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NUTS AND VOLTS

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August 2009

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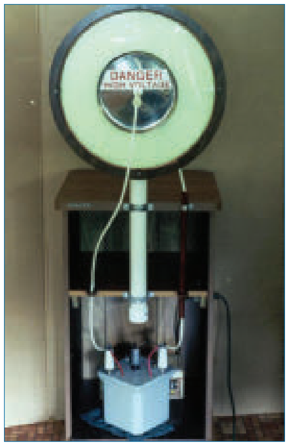

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DEVELOPING PERSPECTIVES

The Golden Age of Electronics

For decades, the underlying assumption has been that everything electronic inexorably progresses to something smaller, faster, more powerful, and less expensive. Microprocessors, RAM, and other high-profile components seem to follow this trajectory. However, most other components, electronic test equipment, and most consumer electronics seem to have fallen off of the evolutionary path. Most of the components and electric devices manufactured today are lighter and cheaper — but to the point that they're apparently disposable. Quality isn't a descriptor that comes to mind.

Take test equipment. It seems as though there are two classes: the commercial gear that starts at $1,000 and the affordable, imported units that consist of a few chips in a case enclosing predominantly air. In consumer electronics, it seems that current offerings are mere shadows of their counterparts manufactured in the recent past. So, should we conclude that the Golden Age of electronics — at least in the US — has passed?

While I'm a realist, I'm not ready to throw in the towel just yet. There are islands of innovation in the domestic consumer electronics industry that have not only resisted, but have leveraged the assault from cheaper imports. Case in point, my Fender Champion 600 — a five-watt, tube-type practice amplifier (**www.fender.com**). It's not clear from the markings where the amp was manufactured, but the components are predominantly Chinese.

I had contemplated buying a tube amp with a richer sound. The hand-built boutique amplifiers were out of my budget range, and I didn't want an inexpensive solid-state amp with only simulated tube sound. As a compromise, I decided to rework the amp with top-grade US components. In searching the web for said components, I found a reference to Mercury Magnetics (**www.mercury magnetics.com**) that markets a variety of amplifier components, including a complete upgrade kit for the Champion 600. After reading a few favorable reviews, I ordered the kit. Within a week, the kit arrived in a small — but deceptively heavy — box. It contained a power transformer, audio output transformer, a choke, a handful of capacitors and resistors, a 15-watt six-inch speaker, and instructions on CD.

The replacement transformers are manufactured in California. In addition to the heavy iron, I decided to replace the Chinese manufactured power tube and the Russian-made preamp with tubes by Groove Tubes (**www.groove tubes.com**), manufactured in San Fernando, CA. These domestic tubes are more expensive than their import counterparts, but to my ears, the improvement in sound quality with the Groove Tubes is well worth the price difference.

The photo shows the Champion 600 case with original components on the left and the upgrade components on the right. The original amp includes a power transformer and small audio output transformer — both imports. In contrast, the upgrade includes a choke for the capacitor-input power supply. Of note is that the upgrade audio output transformer is roughly the same size as the power transformer.

In all, I spent about three hours upgrading my amplifier. I had to drill holes in the steel chassis to accommodate the new transformers, rework the circuit board with a Dremel, remove and then add a few components. On paper, the improvements were significant — lower hum level, better power supply regulation, and a speaker capable of handling the full output power of the unit.

An additional two pounds of iron and handful of components don't guarantee better sound. However, the sound created by the upgrade was beyond my expectation. The sounds were thick and rich as I'd come to expect from a high-end, tube-type amplifier. The upgrade wasn't cheap, but it was a much better value than the available alternatives. And I had fun in the process.

Of course, this is just one example of how upgrading existing electronic equipment — regardless of make — with domestically manufactured components can be a path to nirvana. Of course, with enough money, you can simply buy something better. As an electronics enthusiast, what would be the point in that? After all, anyone can take out their plastic and buy a piece of equipment, use it for a year, toss it in the trash, and buy another. However, few can modify an amplifier or other piece of equipment and have fun while doing it.

Has the Golden Age of Electronics passed? Perhaps in some aspects of the commercial world. But as for as we enthusiasts go, we're making a golden age of our own. **NV**

READER FEEDBACK

BRAVERY IN BOARDING

I want to thank you for the Fred Eady article "From Brain to Finished Board." It gave me the courage to try it. I will say that it took me longer to get the small schematic and the printed circuit board drawn than you or Express PC implied. I had never done anything with a CAD system before and I'm just not computer savvy. Even the fact of doing email is a task for me. It took me two days to get my first attempt to develop the schematic. Another day for the PCB. In the end with three different PC requests to Express PCB, I finally arrived at a usable board. The company threw in other requests after my first attempt. Those changes were a piece of cake to make (so to speak) and new boards were ordered. The last 14 boards came in and the same day I had loaded and connected all the wires, connectors, etc., and the prototype was being tested.

It was a success and I was able to meet with the customer for their inspection. They were well pleased and the project is now in its final phase. I had been requested to do a job that I did not want to bother with. The company kept badgering me so I thought maybe I could outsource the PCB. The Jan '09 *N&V* had an article about surface-mount soldering. If it had not been for the two *N&V* articles, I would not have had the courage. I didn't have to outsource and it took less time to make the board changes. Thanks again for the article.

George Ward

Thanks for reading! I'm really glad that the articles were useful to you. It's also good to hear that you were able to do it all yourself and save some time and surely some bucks. The REALLY good thing about it all is that you now have the power and knowledge to create a professional printed circuit board from scratch! Again, thanks for taking your time to read the articles.

Fred Eady

SHOCKING FIND

There is a safety issue with an article that appeared in the Nov. '08 issue. The section in the Q & A "Device to Scare Animals" uses line voltage to power the audio amp and the greeting card circuit in Figure 4, page 29. In addition, the working voltage rating of C1 is not shown. An inexperienced hobbyist can really get into trouble if he followed this schematic. A safe way to power Figure 4 would be to use a step-down transformer as the power source. In addition, the text indicates that T2 is used in Figure 3, it is used in Figure 4.

Roy Zirillo

Thanks for writing. You are right all around. I did get Figures 3 and 4 mixed up and I should have noted that C1 has to have a voltage rating exceeding five volts. I did say that the circuit using the motion detector lamp was lethal and I put it in a plastic box, but perhaps it would have been better if I only published Figure 3 and kept Figure 4 to myself. I believe that idiots are smarter than any idiot-proofing anyone can devise.

Russ Kincaid

GETTING AMPED UP

I am a long-time subscriber to *N&V*.

The editorial in the March '09 issue caught my eye. I predate the transistor and possibly commercial TV, so vacuum tubes were the things I cut my teeth on. The little preamp with the pencil tubes was too good to pass up so I ordered one yesterday. I am going to run a bass guitar into the preamp. The bass has only tone and volume controls onboard; a passive network without preamp.

My questions for you, based on the editorial are: Did you have any impedance matching problems with the guitar pickup going straight into the preamp?

You mentioned adjusting the plate voltage. If you maintained the same 9V battery for the plate supply, the only way that I think you can change the plate voltage is to adjust the load resistors from 180K to something like 150K or 100K. The tubes are already operating so close to the knee on the plate voltage vs. current curve, there is not a lot of room to change operating parameters. I had thought about using

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P.O. Box 15277
North Hollywood, CA 91615

FOUNDER/ASSOCIATE PUBLISHER
Jack Lemieux

PUBLISHER
Larry Lemieux
publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF SALES/MARKETING
Robin Lemieux
display@nutsvolts.com

EDITOR
Bryan Bergeron
techedit-nutsvolts@yahoo.com

CONTRIBUTING EDITORS
Jeff Eckert, Russ Kincaid, Aaron Ward, Fred Eady, Joe Pardue, Ron Hackett, Louis Frenzel, Vaughn Martin, John Gavlik, Harry Goldman, John Brittan, Joe Croft

CIRCULATION DIRECTOR
Tracy Kerley
subscribe@nutsvolts.com

SHOW COORDINATOR
Audrey Lemieux

MARKETING COORDINATOR WEBSTORE
Brian Kirkpatrick
sales@nutsvolts.com

WEB CONTENT
Michael Kaudze
website@nutsvolts.com

ADMINISTRATIVE ASSISTANT
Debbie Stauffacher

AA cells in series to power the amp and keeping it outboard of the guitar, but in-line with the amp. That gives one the option to raise the voltage to 12V if it does not goof up the regulator supplying the filaments. I have no experience with that particular IC. If you have any thoughts on my comments, I would appreciate hearing from you.

Tom Linbeck

Glad the article sparked your interest. The manufacturer recommends (will ship you with the kit?) a piezo pickup to place inside your guitar cavity. I didn't have any impedance problems using simple capacitor coupling.

Re: the plate voltage, you have it exactly. There isn't much room to play, but the audio changes are apparent even with subtle changes in voltage (depends on how clean you like your guitar sounds). No idea on the 12V supply. However, I found the manufacturer to be VERY responsive to questions. I hope this helps. I found the amp very robust and easy to work with. Not like the old HV amps I grew up with.

Bryan Bergeron

IN THE BLINK OF ...

I read the Das BlinkenBoard article in *N&V's* June '09 issue with much glee. It reminds me of a time in the early 80's when I was installing mainframe mini-computers. I installed one in a property management company and after it was complete, the owner/buyer was wondering where all the blinky lights were. He really wanted blinky lights. He just paid 1/4 million dollars and wanted lights! I went back to the office and started building a dummy panel with LEDs tied into the address and data lines for him. (I could of charged him hundreds of dollars).

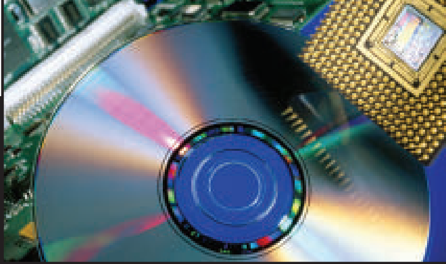
Anyway, it brings back memories. Thanks for the great articles.

Gary

GETTING PERSONAL

I'm a *Nuts & Volts* subscriber. Ever since Vern Graner took over the Personal Robotics column for the magazine I've followed his articles with great interest. The four articles I like the most are the Peanut Butter Jar Monster Detector, the two on the Probotix CNC machine, and the Das BlinkenBoard article. I ordered a BlinkenBoard kit last week and today it arrived, so I'll build it as soon as I have time and follow the updates on that. I want to thank Vern for a continuing series of very high quality articles. What impresses me the most is his highly visible teamwork with his wife and others, and his willingness to give those people credit for their efforts. Together, you have presented many new ideas to readers like me.

Bob Cochran
Greenbelt, MD



■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

LASERS WITH CURVES

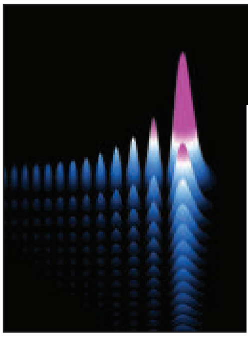


PHOTO COURTESY OF DR. GEORGIOS SIVILOGLOU, CENTER FOR RESEARCH AND EDUCATION IN OPTICS AND LASERS, UNIVERSITY OF CENTRAL FLORIDA.

■ An ideal finite-energy Airy beam.

Backed by the Air Force Office of Scientific Research (**www.wpafb.af.mil/AFRL/afosr**/), an ongoing effort is underway at the University of Arizona's College of Optical Sciences and the Arizona Center for Mathematical Sciences to create curved laser beams that can be used to detect explosives and chemical/biological agents in remote locations. The research is based on Airy beams, a strange type of optical wave that resists diffraction over long distances and can accelerate freely during propagation.

Prof. Demetrios Christodoulides, of the University of Central Florida, has explained the bending process. "[The beams] are made up of a combination of waves, one leading one, which carries most of the beam's intensity and many smaller trailing waves. These waves interfere with each other so that the leading wave curves one way while the tail bends in the opposite direction."

Apparently, such beams are "self-healing" in that they can easily reassemble themselves after being blocked or distorted in the atmosphere, which would make them useful for passing through turbulence and fog. Unfortunately, physicists still need to come up with ways to extend the laser-generated light filaments and plasma channels over long enough distances for real-life applications. It was ruefully noted that "the practical use of laser filaments may be years away, because the pulse shape is not predictable, and that makes control, which is much needed, impossible." But research continues.

QUANTUM ERROR SUPPRESSION

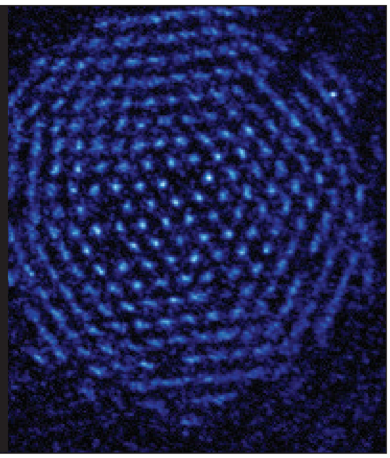


PHOTO COURTESY OF NIST.

■ Crystal consisting of about 300 ions spaced 10 m apart and fluorescing.

If you've been experiencing data errors with your quantum computer (and who hasn't?), you'll be relieved to know that the National Institute of Standards and Technology (NIST, **www.nist.gov**) has demonstrated a technique for suppressing them. The method counteracts the vulnerability of quantum memories to be disrupted by stray electromagnetic fields, which can show up as random errors in the quantum bits (qubits).

The demonstration involved an array of about 1,000 ultracold beryllium ions trapped by electric and magnetic fields with each ion acting as a qubit of storage. The ions formed a neatly ordered crystal, similar to arrays of qubits fabricated using semiconducting and superconducting circuitry. The NIST team then applied customized sequences of microwave pulses to simultaneously reverse error accumulation in all of the qubits. It was observed, "simulations show that, under appropriate conditions, this method can reduce the error rate in quantum computing systems up to a hundred times more than comparable techniques."

The method is not entirely novel, being an adaptation of "spin echo" techniques used for decades to suppress errors in nuclear magnetic resonance. But we won't tell anyone.

COMPUTERS AND NETWORKING

DISNEY ENTERS NETBOOK MARKET

It seems that the PC industry has somehow failed to adequately address the surfing needs of 6- to 12-year-olds, but never fear, because Disney Consumer Products (**www.disneyconsumerproducts.com**) and ASUS Computer International (**www.asus.com**) have collaborated to develop the Disney Netpal netbook.

■ The Disney/ASUS Netpal netbook.

PHOTO COURTESY OF DISNEY CONSUMER PRODUCTS.

According to Disney, it's designed with both parents and kids in mind, offering a durable, reinforced mechanical design and a "truly magical and engaging computing experience with a unique Disney user interface." Features include 40+ parental control options, Wi-Fi, Windows XP Home, and software featuring Disney characters and icons. Browsers and email applications have extra filters to keep the tots from stumbling upon your favorite websites, and parents can even control their email contacts. User interface is via the Disney Magic Desktop "gadget tray," which consists of a 2D menu displaying Disney-themed email, the Disney-themed browser, and the parental control options. It also comes with 15 kid-friendly widgets, including a stopwatch, a digital memo pad, and a calculator. In terms of hardware, you get a spill-proof keyboard, a backlit 8.9 inch LCD display, an Intel ATOM N270 processor, and a gigabyte of memory. It also comes with a 0.3 Mpixel camera, built-in stereo speakers, and an analog microphone. Curiously, there are two versions — the MK90H and the MK90 — with the latter sold exclusively by Toys "R" Us. The only apparent difference is that the MK90 comes with 16 GB of solid-state storage, whereas the H version has a 160 GB hard drive.

Either one will run you $349.99 retail (carrying case extra), which provides about the same value level as the $6 gristleburgers sold at Disney theme parks. But, hey, you get your choice of Magic Blue or Princess Pink.

NEW PORTABLE HARD DRIVE

Since tossing my 100 MB SCSI zip drives into the attic a few years ago, I hadn't heard much from Iomega (**www.iomega.com**), but it turns out they're still around. In fact, you can still buy zip drives, and they now hold up to 750 MB on the removable discs. But the company's latest is the eGo™ USB 2.0-powered portable hard drive line, available with capacities up to 500 GB.

Inside the anodized aluminum shell is a 2.5 inch mechanism that's protected by Iomega's Drop Guard® feature, said to allow it to fall harmlessly from heights of up to 51 in (1.3 m). But if you're exceptionally clumsy, consider the BlackBelt version, which comes with a black eGo Power Grip Belt and Drop Guard Xtreme. This one allows you to drop it from as high as 7 ft (2.1 m).

Bundled with the drives is the Iomega Protection Suite, a portfolio of backup and antivirus software providing protection for photos, videos, music, etc. System requirements are Windows 2000 Pro, XP, or Vista, or Mac OS X 10.4 or above. List prices are $84.99 (250 GB), $94.99 (320 GB), and $134.99 (500 GB). The BlackBelt model is only an extra $5. All include a three-year warranty.

ANOTHER SEARCH ENGINE ONLINE

Yeah, just what we needed — another search engine. But the recently launched Wolfram|Alpha (**www.wolframalpha.com**) is at least a bit different. Instead of blindly giving you a list of other websites to visit, it attempts to provide an organized summary of information that actually answers your question. According to a press release, "The long-term goal of Wolfram|Alpha is to make all systematic knowledge immediately computable and accessible to everyone. Wolfram|Alpha draws on multiple terabytes of curated data and synthesizes it into entirely new combinations and presentations. The service answers questions, solves equations, cross-references data types, projects future behaviors, and more."

The key term here is "long-term." Right now, those multiple terabytes translate into only a limited range of information. It's noteworthy that W|A draws heavily on Mathematica, a technical computing software platform developed by Stephen Wolfram himself. As a result, it does a nice job of calculating things and providing numerical data. For example, it quickly informed me that the distance to Jupiter is 416.1 million miles and that the time in Beijing was 4:53 a.m. It even knew the resistivity of aluminum. But if you search for more general information, you'll soon encounter the dreaded response, "Wolfram|Alpha isn't sure what to do with your input." This was the answer when I entered, among others, the following expressions: new york hotels, roulette rules, tuna casserole, transmission repair, stirling engine, trout fishing tips, nausea cure, understand women, and clone my poodle. Any search engine worth it's salt surely must be able to address such burning issues. Maybe someday.

CIRCUITS AND DEVICES

FAST NEW ASSEMBLY BOT

Okay, you probably don't need one in your own workshop, but the FANUC M-1iA assembly robot — introduced at the 2009 Robots & Vision show — is pretty impressive. It's a lightweight, compact, six-axis, parallel-link robot designed for small parts handling and high-speed picking and assembly. It can be installed in a variety of orientations and has a three-axis wrist (a four-axis version is available, as well). If you scale back to a single-axis wrist, the machine is capable of speeds up to 3,000 degrees per second. According to FANUC, "The M-1iA's flexibility and speed far exceed the capabilities of other vertically-articulated or SCARA-type robots."

The 37.5 lb (17 kg) bot operates via an R-30iA controller with integrated intelligent functions such as

■ A pair of FANUC. The M-1iA robots assemble and disassemble a 10-key keyboard.

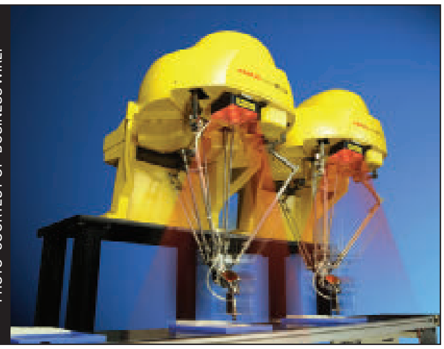


PHOTO COURTESY OF BUSINESS WIRE.

iRVision®, Robot Link, and Collision Guard. As many as 10 of them can be linked through a network exchange of robot positional data, and each can be removed from its stand for integration into another machine. For details and videos of FANUC bots in action, drop by www.fanucrobotics.com.

MACHINE INTERFACE MADE EASY

■ Design your own machine interfaces and sensor processors with the MPLAB Starter Kit.

If you're interested in human-machine interfaces and intelligent sensor processing designs, Microchip Technology has a deal for you. The recently released MPLAB Starter Kit for PIC24H MCUs "includes everything needed to develop and evaluate human-machine interfaces and intelligent sensor processing for embedded designs." The kit is based on the PIC24HJ128GP504 16-bit microcontroller, which features up to 40 MIPS performance, 128 kB of Flash, 8 kB of RAM, and a full complement of integrated peripherals. For advanced HMIs, the kit includes an OLED array display that is supported by the free Microchip Graphics Library, low-cost audio and speech playback capability for user prompts, and user-input capabilities.

For intelligent sensor processing development, the kit board has a tri-axial analog accelerometer interfaced to the PIC24H, along with example applications such as motion-sensitive gaming. The best part is that you can pick it up for $59.98 at **www.microchipdirect.com.**

SMALLEST DC/DC CONVERTER INTRODUCED

If you're tight on space and need a step-down DC/DC converter, you might be interested in the latest model SWIFT™ power management IC from Texas Instruments (**www.ti.com**). Billed as the industry's smallest single-chip, 6-A, 17-V step-down synchronous switcher with integrated FETs, the TPS54620 is about half the size of the usual multichip converters in a 3.5 mm sq QFN package. The 1.6 MHz monolithic DC/DC device supports input voltages from 4.5V to 17V, allowing it to manage space-constrained 5V and 12V point-of-load designs such as wireless base stations and high density servers. Specs also call for accuracy of + or - 1% over temperature and 95% power efficiency. Suggested pricing is $1.95 in 1,000 unit quantities. **NV**

INDUSTRY AND THE PROFESSION

CLONE MAKER GOES CHAPTER 11

The protracted legal battle between Apple and Mac clone builder Psystar (**www.psystar.com**) appears to be over, at least for now, as the latter filed for Chapter 11 bankruptcy late in May. This effectively put a stop to Apple's lawsuit, which was scheduled for a November trial. Psystar claimed to have assets of less than $50,000 and somewhere between $100,000 and $500,000 in debts, with the biggest creditor being the law firm that has been defending it against the copyright infringement suit. The company claims to have solid plans for continuing in business, however, and as of this writing is still online and selling its machines, which start at $599 for a box with a 2.5 GHz dual-core E5200 processor, 2 GB of memory, a 500 GB drive, and OS X Leopard preloaded.

FACEBOOK WORTH BIG BUCKS

Reportedly, social networking site Facebook (**www.facebook.com**) was experiencing some growth-related cash flow issues earlier this year and alleviated the problem by selling a 1.96% share in the company to Digital Sky Technologies for $200 million. A quick consultation with a pocket calculator reveals that, assuming the investors aren't complete idiots, Facebook must be worth a little better than $10.2 billion. That may sound pretty high but, in fact, Microsoft shelled out $240 million for a 1.6% bite of the company in 2007, which would indicate that Facebook was worth $15 billion at the time. Either way, that's a nice chunk of change for a company that doesn't have to manufacture, package, or ship anything.

■ BY RON HACKETT

PROGRAMMING YOUR SERIALIZED LCD DISPLAY

IN THE PREVIOUS INSTALLMENT OF THE PRIMER, we constructed a stripboard version of a PICAXE-14M circuit that converted a standard parallel LCD into a serial display. By now, you probably have completed and tested your display. If not, you may be interested in the printed circuit board version of the project (available at www.JRHackett.net) because this month we're going to turn our attention to some of the details of programming the display. Specifically, we'll investigate two of the most useful features of LCD displays: scrolling a long line of text across the relatively small width of the display and creating custom characters to enhance the functionality of the display. However, before we get to that we need to review some of the basics of HD44780-based displays.

HD44780 BASICS

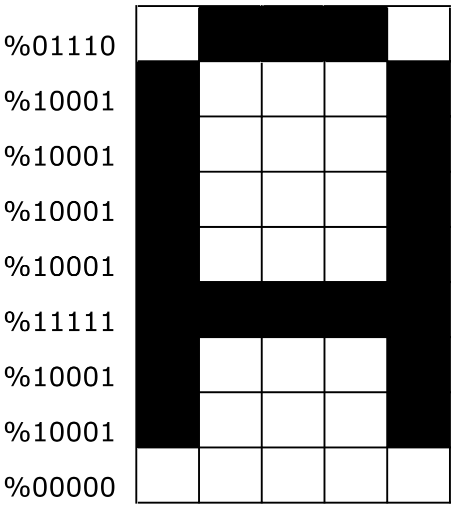
Search the web for "HD44780" and you will find a considerable amount of relevant information. Here's a brief list of the resources that I have found to be the most useful. If you would rather not type in the URLs, the links are also available on my website (**www.jrhackett.net/projects.shtml**).

- HD44780 DataSheet: **www.sparkfun.com/datasheets/LCD/HD44780.pdf**
- HD44780 Tutorial.1: **www.epemag.wimborne.co.uk/lcd1.pdf**
- HD44780 Tutorial.2: **www.epemag.wimborne.co.uk/lcd2.pdf**
- HD44780 and PICAXE: **www.hippy.freeserve.co.uk/picaxelc.htm**

While you're online getting the above resources, you may also want to download the programs we will be experimenting with this month. They are all available from the *Nuts & Volts* website (**www.nutsvolts.com**) or from the "Projects" section of my site:

- LCD16x2-CharTest.bas
- LCD16x2-ScrollDemo.bas
- LCD16x2-CustCharDemo1.bas
- LCD16x2-CustCharDemo2.bas
- LCD16x2-CustCharDriver.bas
- Serout2LCD-CustCharDemo.bas

■ FIGURE 1. HD44780 Character Chart.



■ FIGURE 2. Pixel Def for Capital "A."

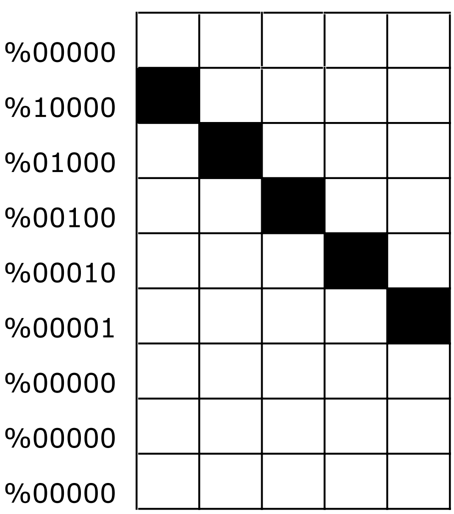
Figure 1 gives the Character Codes as shown in the HD44780 datasheet (Table 4, page 17). The datasheet actually includes two different Character Code tables, but I tested the 16x2 LCDs that I have and all of them match what is shown in Figure 1. Now would be a good time to test your own LCDs to see if they also match the Figure 1 data. To do so, you can use the "LCD16x2CharTest.bas" program, which simply displays all the characters in the last two columns in Figure 1.

If you compare the "CharTest" code to what we used in the previous installment, you will see that I made a couple of minor modifications: the initialization routine is no longer a subroutine (because it is only called once, anyway) and the "OutByte" subroutine is slightly different. Neither of these changes were needed for "CharTest" but as we will soon see, I had problems running out of memory in the 14M in the final version of the LCD driver software and these changes saved a few bytes of memory. For the sake of consistency, I decided to use the same code in all of the programs this month. Later, when we discuss the final version, I'll explain the changes in detail. Even if your LCD character codes are different from Figure 1, you will still be able to do everything that we are about to discuss because most of the printable ASCII characters (from character 32 to character 127) should be the same. Before we discuss the exceptions to this rule, I should explain how to determine a character's code from Figure 1.

As an example, take a look at the capital "A" character: its column heading (0100) contains the upper four binary bits of the code and the row heading (0001) contains the lower four binary bits, so "A" has a binary code of %01000001. (The PICAXE compiler always uses "%" to indicate that a number is binary.)

If you are familiar with binary-to-decimal conversions, you'll know that 65 is the decimal equivalent of this code. If not, you have at least two choices. You can do a web search for "binary to decimal" to quickly locate a tutorial or you can use the Programming Editor as follows: Under the "view" menu, select "calculator" and then use its menu to select "scientific." Then click on the "Bin" radio button and use either the mouse or the keyboard to enter "01000001." Finally, click on the "Dec" radio button to see the decimal equivalent.

■ FIGURE 3. Pixel Def for Backslash.



Now let's look at the exceptions that I mentioned earlier. First, the standard ASCII character 92 (I'll let you do the decimal-to-binary conversion) is a backslash ("\"), but the HD44780 substitutes a Yen symbol. (We will soon see how to include a backslash as a custom character.) The other two non-standard character codes are 126 and 127 which are listed in Figure 1 as left and right arrows. Even though they are not standard ASCII characters, they can sometimes come in handy.

DISPLAY SCROLLING

All two-line HD44780 LCDs have 40 storage locations for each line. For a 16x2 display, this means that we can write 40 characters to each line. Of course, only 16 characters can be visible on a line, but the other 24 characters are stored sequentially in the LCD's memory and can be accessed by scrolling the display. There are two commands for this purpose: command 24 scrolls the text one character to the right and command 28 scrolls the text one character to the left. If you continue scrolling beyond the 40 character limit, the text "wraps around," so an infinite loop of "scroll left" commands will cause the 40 character line to continuously circle through the display window. It's not possible to scroll only one line; both lines scroll simultaneously. Also, it's important to remember that this is character scrolling, not pixel scrolling, so the effect is a little "jumpy" and requires some delay between each shift of the line in order for the display to be comfortably readable.

Our next program (LCD16x2-ScrollDemo.bas) is a simple demonstration of display scrolling. It scrolls a 40 character (including the final "space") sentence three times to the left and three times to the right, repetitively. Download the program, install it into the 14M on your display, and watch it scroll! You may want to experiment with adjusting the speed of the scrolling to find a rate that feels comfortable. Also, see if you can modify the program so that a second sentence is stored in the line 2 display locations, so both sentences are scrolled simultaneously. When you're finished experimenting, we're ready to move on to "user-defined" characters — a topic which is slightly more complicated but much more useful.

COMPLIANT USER DEFINED CHARACERS

The HD44780 controller includes storage space for eight user-defined characters that can be stored in RAM at data locations 0 through 7. If you look again at Figure 1, you can see

that, for some reason, these characters are duplicated at locations 8 through 15. We'll actually find a good use for that duplication before we're done this month, but first let's take a look at the process of defining a custom character.

All the characters displayed by the HD44780 are based on a matrix of eight rows of five pixels each. **Figure 2** presents the pixel definition for a capital "A" along with the binary value associated with each row of five pixels (a black pixel = 1 and a white pixel = 0). As you can see, the bottom row of pixels isn't used at all. This row is reserved for the "underline cursor" (if you choose to display it) so, as a rule, whenever you define a custom character you should leave the bottom row blank (%00000). In our next program, we're going to follow that rule but later on we'll get to break it. (Don't you just love it when you can do that?)

For our first custom character, we're going to define the backslash that the HD44780 left out — its pixel definition is presented in **Figure 3**. I should mention at this point that you can also use decimal numbers to represent the value for each row of the custom character definition. However, as you can see in Figure 3, binary numbers have the distinct advantage in that the pattern of 1s in the number matches the pixel layout. Also, we don't have to do the binary to decimal conversions — the PICAXE compiler automatically does that for us. Before we get into the mechanics of how to include a custom character definition in a program, download and print out a copy of our next program (LCD16x2-CustCharDemo1.bas) for reference in the following discussion.

The easiest and least memory-intensive method of programming a custom character is to use "eeprom" or "data" statements — it doesn't matter which one you use, they're synonymous. If you look at your printout, you can see that I have defined eight custom characters which is the maximum that the HD44780 allows. To do so, I used a total of 64 "data" statements; eight for each character. (Actually, there are 65 statements, and the last one may lead you to conclude that I have lost my mind, but just ignore it for now — we'll get to it soon.) I also used comments with an appropriate pattern of asterisks to remind myself of the character definition.

As you can see, I didn't specify any locations in the data statements. If you omit them, the compiler automatically begins at EEPROM location 0 and proceeds consecutively. In other words, the 64 values will be stored in locations 0 through 63 which are the values used later in the program to read the data and transfer it to the HD44780.

According to the HD44780 datasheet, any command between 64 and 127 can be used to initiate data transfers to the CGRAM. I found this confusing at first, but it turns out that the HD44780 functions just like the PICAXE. The eight CGRAM locations actually consist of 64 bytes of memory (eight bytes per character, just like our data statements). Issuing a command of 64 begins the data transfer at the first "row" of the first character; all subsequent data is automatically stored sequentially until the HD44780 receives another command (e.g., "place the cursor at the beginning of line 1").

So, looking again at the program printout, you can see how this process is implemented in the "Load custom characters into CGRAM" portion of the code. Once the command of 64 is issued, the for/next loop simply transfers all 64 bytes of data sequentially to the HD44780 until it has filled the 64 locations that define the eight custom characters.

Next, the command of 128 moves the cursor to the beginning of the first line of the display and the following for/next loop outputs 16 (not eight) characters. I did this to demonstrate how the HD44780 automatically duplicates the custom characters. When you run the program, you will see each of the eight characters appearing twice. (As I mentioned earlier, I don't know why it works this way, but that's what happens.) Once you have the program running successfully, you may want to spend some time redefining some (or all) of the custom characters. When you feel comfortable with how the process works, we'll be ready to move on and get a chance to break the rules!

DEFIANT USER-DEFINED CHARACTERS

Not that anyone has ever asked, but I have never liked how text appears on character-based LCDs. I included the "jolly pig" sentence in the last program just to make my point: There are five lower-case characters in the English alphabet ("g," "j," "p," "q," and "y") that are meant to have descenders that extend below the main body of the letter, but every character LCD I have ever used ignores this fact. Run the previous program again, and you will see what I mean. The lower-case "g" is ridiculously large, the "p" looks like a small capital "P" and the "q" just looks stupid. (The "j" and the "y" aren't too bad — I'll grant you that.) In any case, user-defined characters finally give me the power to correct this appalling state of affairs and to break a rule while I'm at it, so it's a win-win situation! That's exactly what we're going to do in our next program (LCD16x2- CustCharDemo2.bas). Again, download the program and print it out for reference.

As I mentioned earlier, the purpose of leaving the bottom row empty is to allow space for the underline cursor. However, in all my projects (so far) I don't use the LCD to enter data, just to display or select it. As a result, I never show the cursor anyway. Even if I did, I could easily see where it is in spite of the occasional stray pixel on the bottom line, so it's a small price to pay to gain the readability of true lower-case descenders.

As you can see in the program printout, I have defined the five lower-case letters in question, and have used the bottom row to do so. (I also left in three of the original custom characters, but they aren't used in the program.) The final two data statements store my two sentences (minus the period) in two different forms. The first one uses the "standard" characters; the second one uses my new and improved versions. Admittedly, the second data statement is cumbersome

■ FIGURE 4. "Jolly Pig" Display.

■ FIGURE 5. "Quiet Pigs" Display.

and confusing, but we'll rectify that shortly. For the time being, just be aware that my "j" is stored at location 3, my "y" is at location 4, etc. With this in mind, you can see that the last data statement corresponds to (but improves upon) the penultimate one. Download the program to the 14M, run it, and compare the two lines. (**Figure 4** is a photo of the program's display.) You can decide for yourself whether the improvement is worth the effort. Even if you decide that it isn't, in our next program we're going to simplify how the custom characters are substituted for the standard ones; the technique involved will be useful whenever you want to do custom character substitutions.

IMPROVING THE LCD DRIVER SOFTWARE

So far, we have been experimenting with demo programs for our 14M-based LCD display. The next logical step is to modify the driver software for the display so that our master processor can take advantage of the improved functionality of the display. Our next program (LCD16x2-CustCharDriver.bas) will do exactly that. As usual, it would be a good idea to download it and print out a copy for reference. As I mentioned earlier, I had considerable difficulty developing the new LCD driver software because I kept getting "out of memory" errors along the way. This problem stems from the fact that the 14M only has 256 bytes of program memory, and this memory is shared with its data memory area. In other words, every byte of data we declare at the beginning of the program decreases the available program memory by one byte. I won't bore you with the details of the problems I encountered. Suffice it to say that, because I was determined to use my nice new lowercase letters with true descenders, I was forced to give up two things along the way. First, I eliminated the main "if" statement from the previous driver. Now the program only accepts data input at 4800 baud and moving the baud jumper has no effect. Actually, that really isn't much of a sacrifice at all because I found that I never used 2400 baud, anyway. However, that change still didn't free up enough memory for the new "select case" statement that I needed to handle the custom characters. (We'll get into the details of the "select case" statement shortly.) I also had to give up two of the eight possible custom characters, so I ended up with my five new and improved lowercase letters and (a "bullet").

Before we discuss the details of the new "select case" statement, let's back up for a minute to see why some changes were necessary in the first place. In the version of the software that we used in the last column, we used a simple method of distinguishing between a command byte and a text byte. At that time we were only printing ASCII characters which all have values between 32 and 127. The commands we used were all either less than 32 or greater than 127, so all we had to do was test the value of the incoming byte and set Rsbit accordingly. However, this month I realized that I also wanted to use a couple of the characters on the right side of the HD44780 character chart (especially the "degree" symbol at %11011111 and the "?" symbol at %11110100), so I needed a new way for the master processor to communicate which bytes are commands and which ones are text. I also knew that a "select case" statement would be the simplest way to implement the automatic replacement of the obsolete lowercase letters with my new custom versions, so I decided to also handle the text vs. command issue in the same "select case" statement.

Refer to your printout of the LCD16x2-CustCharDriver.bas program as we take a detailed look at the new "select case" statement. As you can see, it handles three different cases. The first case statement applies to characters 103, 112, 113, and 106. (If you look at the Character Chart back in Figure 1 and decipher the binary addresses, you will find that these are the values associated with g, p, q, and j, respectively.) Subtracting 103 from each of these values, we end up with 0, 9, 10, and 3. If you recall that the eight custom characters stored at locations 0-7 are also duplicated at locations 8-15, you can see that (fortunately for us) locations 0, 9, 10, and 3 magically become locations 0, 1, 2, and 3. As a result, we end up with the new versions g, p, q, and j that we initially stored at those locations. Unfortunately "y" doesn't fit into the same pattern, so we need the second case statement to change its value from 121 to 4.

The third case statement within the "select case" statement provides us with considerable flexibility. In effect, it transforms any character with a value between 128 and 207 (inclusive) from "text" to "command." It does this by simply assigning the "cmd" value to Rsbit. Therefore, when the character is output to the LCD later in the subroutine, it is interpreted as a command. Since line 1 of the display begins at location 128 and line 2 begins at location 192, this gives us the ability to move the cursor to any screen location and we only need to transmit one byte to do it. The price we pay for this flexibility is that we can't access any of the characters in the HD44780 chart that are in the columns headed by %1010, %1011, or %1100.

Since I'm only interested in a few of the characters in the last three columns of the chart, that's fine with me. If you disagree, you will need to change the "select case" statement to suit your needs. One last point: At the end of the subroutine, RSbit is reset to

"txt" so the next byte will again be interpreted as text.

TESTING THE NEW LCD DRIVER SOFTWARE

In order to see how the new LCD driver software functions, we need a master processor program to send the serial data. Our final program (Serout2LCD-CustCharDemo.bas) does just that. I guess I have pigs on my mind this month (probably because it's BBQ season) since they are in this one too. In any case, it's the process (not the pigs) that's important. This simple program demonstrates how two values displayed at two different locations on the LCD screen can be easily updated using one nine-byte data packet. To see how this is accomplished, use the Programming Editor to download "LCD16x2-CustCharDriver.bas" to the 14M on your LCD board and then download "Serout2LCD-CustCharDemo.bas" to the 28X1 on your master processor board. When everything is functioning properly, you should see a display similar to **Figure 5**. (You may need to cycle the power to both boards to synchronize the communication link and obtain a readable display.) Once you have the two programs communicating successfully, we can examine the "serout" command in the "Update" subroutine. (Refer to your printout.) After the initial "Q1" command (which places the cursor at the beginning of line 1), the value of 132 (which is in the range of 128 to 207) gets reinterpreted as a command by the LCD driver software and the cursor is moved to location 132 (the fifth character in line 1). Next, the "#pigs" value gets displayed at that location. You may recall that the "#" symbol converts the value from a number to a series of ASCII digits. For example, if the current value of the variable "pigs" is 3, "#pigs" sends a value of 51 (which is the ASCII code for the digit 3). If you forget to include the "#" symbol (which I did at first!), the actual value 3 is transmitted, resulting in a j at location 132 because we defined j at location 3 in the CGRAM memory. The next two bytes in the "serout" command (201 and "#jigs") work in exactly the same way — the ASCII value of "jigs" is displayed at the 10th position of line 2. Finally, the four "Q1" bytes simply complete the required nine-byte transmission packet by repetitively placing the cursor at the first position of line 1 which produces no visible change in the display.

ENOUGH WITH THE PIGS, ALREADY! FLASH!

Writing this month's column was an interesting experience. Trying to clearly explain the details of the various programs we covered turned out to be much more difficult than any of the hardware-focused installments so far. (I hope it's easier to understand than it was to write!) In any case, I need to take my mind off pigs for a while — except for the baby-back ribs I'll smoke for dinner. **NV**

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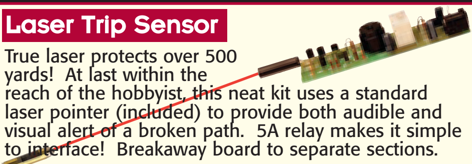

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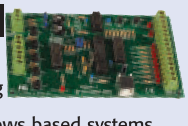

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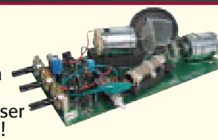

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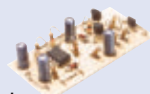

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

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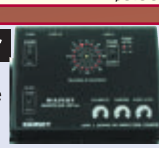

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

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Delivers a super clean 20W output from one SMT package! Ultra efficient class D design produces no heat. PCB can be snapped into a small circle for special applications. Runs on 18VDC for rated output, or down to 10VDC for reduced output.

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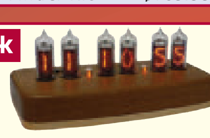

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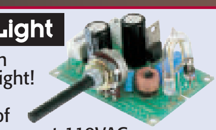

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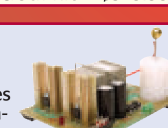

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

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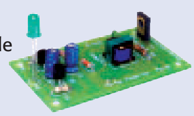

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

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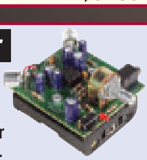

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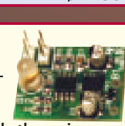

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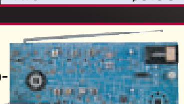

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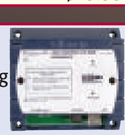

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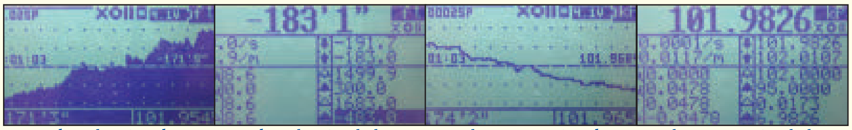
- ✔ Pressure resolution greater than 0.0001kPa!
- ✔ Displays and logs realtime elevation & pressure changes!
- ✔ USB interface for easy data transfer!
- ✔ Built-in Li-Ion battery with automatic multi-source charging!

The response to the UP24 was incredible! Customers from professional land surveyors, meteorologists, scientists, pilots and hikers to the curious hobbyist were overwhelmed with its sensitivity and accuracy. Reading realtime elevation to a third of an inch and pressure displays in Pa, KPa, mb, bar, inHg, atm, and feet of water really blew their minds! Even with this response we considered it a challenge to make it even better... and we sure did! Introducing the next generation UP24B!

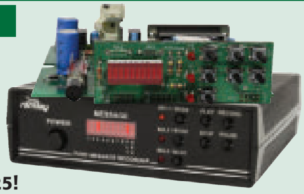
Now you can charge the internal Li-Ion power cell from either an external source of 6VDC to 30VDC or a standard 5VDC USB connection from a PC, laptop, or USB charger! Charging status and battery condition displays are also provided. Next we added a "MARK" feature. This allows storing a single data point reading when YOU want instead of blindly storing readings at the selected sample rate. A simple dry or electronic closure is all you need to set a mark or start point.. Each mark you add creates a new data block. Hi-res atmosphere changes to elevation changes less than a third of an inch don't even scratch the surface or specs of the UP24B! Visit www.ramseykits.com for complete info and applications.



Elevation Graph *Elevation Statistics* *Air Pressure Graph* *Air Pressure Statistics*

UP24B	High Resolution Air Pressure & Elevation Sensor Kit	$239.95

Digital Voice Messaging System



- ✔ Up to 8 minutes of total message time!
- ✔ 2, 3, or 8 separate message versions!
- ✔ Automatic or manual message playback!
- ✔ DTMF BCD remote operation option!
- ✔ Line and speaker level audio outputs!
- ✔ Line and mic level audio inputs!
- ✔ Non volatile message memory!
- ✔ Complete remote operation with one DB25!
- ✔ Great for one-touch on-demand announcements product kiosks, trade shows, emergency messages museum displays, and a whole lot more!

A few years ago we brought the emerging technology of digital voice storage to the hobbyist with the Bullshooter digital voice storage kit. Then, as the technology improved, so did ours when we introduced the next generation, the Bullshooter-II. To this day it remains extremely popular for digital voice storage for messages, endless "tape loops" and radio broadcast announcements. But when a number of major museums came to us to develop a similar low-cost unit for on-demand multi-language voice storage for diorama displays, we figured it was time to really get creative. In response, the DVMS series was created that not only met all of their requirements, but also kept their bean counters happy with the low cost!

The intent - to be able to record and playback up to 8 separate digitally stored voice messages with the press of a single button or two. Let's look at a typical museum diorama display. A detailed description is present on a plaque, but there is too much information to have printed. Plus, what about different languages? All of a sudden there would be signs, signs, everywhere there's signs! It just doesn't work. But what if there was a basic sign or plaque identifying the object, followed by push buttons properly labeled for each language desired. It's intuitive to push the button labeled "English" or "Espanol", and a nice narrative can start in any language selected! Some of the museums built the DVMS into their main display sign, others remoted the switches to a bank of units for easy recording and maintenance. It sounds simple, it is simple, and it works great!

A standard DB25 style connector provides the ability to connect remote function controls and indicators to the unit so you can customize your controls to meet your needs. And in addition to the 2, 3 and 8 message versions, a special version is available to allow simple direct selection with a 3 wire interface, (BCD), of any of the 8 messages from a digital controller such as the brand new DCI2 DTMF control interface or a computer and then use the play, stop, and pause controls to control the message. You can even configure the DVMS to provide continuous looping of a message with programmable delays of 0, 0.5, 5, and 30 secs, 1, 10, 30, and 60 minutes. The main unit has all the function and display controls on the front panel which can be disabled with a lock code to prevent unauthorized tampering. RCA unbalanced line level outputs are provided for easy connection to any amplifier, amplified speaker, mixer, or sound system. In addition, a standard 4-8 ohm speaker output is provided to directly drive a monitor speaker. This is frequently built-in to museum displays! All versions are determined by firmware changes, and can be easily reprogrammed in the field to change the configuration desired! Visit www.ramseykits.com for details!

DVMS2	Digital Voice Message System Kit, 1-2 channels	$99.95
DVMS2WT	Factory Assembled & Tested DVMS2	$149.95
DVMS3	Digital Voice Message System Kit, 1-3 channels	$99.95
DVMS3WT	Factory Assembled & Tested DVMS3	$149.95
DVMS8	Digital Voice Message System Kit, 1-8 channels	$99.95
DVMS8WT	Factory Assembled & Tested DVMS8	$149.95
DVMS8BCD	Digital Voice Message System Kit, 1-8 Ch, BCD	$99.95
DVMS8BCDWT	Factory Assembled & Tested DVMS8BCD	$149.95

OBDII CarChip Pro

- ✔ Monitor vehicle performance to save gas!
- ✔ Stores up to 300 hours of trip details!
- ✔ Records time, date, distance, speed, events and up to 4 separate engine parameters!
- ✔ Records extreme acceleration and braking!
- ✔ Automatic accident log, records the last 20 seconds before impact!
- ✔ View and reset engine diagnostic trouble codes!
- ✔ Test for preliminary emissions status!

Once again, no comments are necessary about the summer gas prices. Last summer they topped over $4 a gallon. Just look what's happened in the last 30 days leading into the summer of 2009 after what seemed like record lows all winter...

Up $.49 in one month! And this month it continues to climb. At that price it's more important than ever to make sure your vehicle is in tip-top shape for the most economical performance possible.

Did you know old spark plugs can reduce fuel economy by 30%? It gets worse... a bad oxygen sensor cuts it by 40%! And that relates to a lot of extra gas and at 4-5 bucks a gallon, just do the math... That's a LOT of money!

With the CarChip Pro you'll have complete access to all your vehicles diagnostic data at your fingertips! Sort miles by type (business, personal or driver), set thresholds for alarms, calculate gas mileage, log extreme acceleration and braking, speed, engine parameters, and a whole lot more! And as you know, extreme acceleration does not equal fuel economy! Find out who's driving your vehicle like a race car...and deal with it!

The CarChip Pro is great if you have a new driver in the family. Easily monitor their performance and let them gain additional privileges with a good driving record! You have the proof! Can it get any better than that? You bet! You know that annoying "check engine light" (multifunction indicator light) that comes on? You will be able to read the diagnostic trouble codes (DTC's) get the status, date, and time of each trouble code, and reset the light!

CarChip Pro includes storage for up to 300 hours of driving data! If you're unfortunate enough to be involved in an accident, it even records all the vehicle's parameters for the last critical 20 seconds of operation! Includes USB cable, software and complete instructions.

8226	Davis OBDII CarChip Pro Data Logger	$99.95

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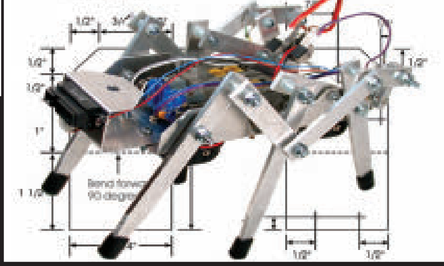


■ GUEST HOSTED BY SAMUEL AARON WARD

SOLAR TRACKER

With the state of the world today – diminishing oil supplies, global warming, acid rain, and so forth - it's no surprise that everyone is going green. With last year's gas hike and the current economic recession, people are looking for ways to do more with less, leaving as little impact on the environment as possible. Phrases such as "going green" and "carbon footprint" have become ubiquitous and even trendy. The United States Green Building Counsel (USGBC) has even developed a green building rating system called LEED by which new buildings are designed to be as energy efficient as possible. Those with the knowledge to innovate technologies for renewable resources might soon find themselves highly sought after!

WEST VIRGINIA UNIVERSITY INSTITUTE OF TECHNOLOGY

I graduated with my degree in Electrical Engineering from WVUIT in May 2008. As a senior, one of my requirements for graduation was completing a two-semester Senior Design course in which I would be teamed up with two other students to design and construct a mechanism which should encapsulate everything we learned during our time at "Tech." My goal was to design a green machine which interacts with its environment, comprised of three basic components: devices for input, processing, and output. I, therefore, started with the assumption that I would need someone good at designing electronic circuitry, someone good at computer programming, and someone with a strong mechanical skill set. Though only a novice, I decided that I would tackle the electronics.

On the first day of class, I quickly assessed my five classmates: four electrical engineering students and one computer engineering student. I immediately approached Adam Vincent, the "CompE" major, and asked if he would join my team. He agreed, and I had my software guy. Of the remaining four, I really only knew one of them, Mike Browning, who is a good friend. Mike was older, had worked in industry for years, and possessed a wealth of practical experience. I had my mechanical guy. Together, we three made quite the well-rounded team. We were ready to get to work!

BRAINSTORMING FOR IDEAS

If you caught an episode of the short-run Discovery Channel program *Prototype This*, you pretty much have the gist of a Senior Design project — only with two semesters instead of two weeks in which to complete it. We were given a budget of only $200 per semester and had to impose our own requirements and constraints on the project. What should we create?

I wanted to design a complete embedded system with custom electronic circuitry. Adam needed something with a fair amount of computer programming to meet his objectives as a computer engineering major. Mike wanted to do something with renewable resources, which narrowed our options considerably. We had available to us a solar panel donated to the department by a recently retired professor, so we decided to go with solar power.

Once a week, we met with Dr. Stephen Goodman, Ph.D., Senior Design instructor and Chair of WVU Tech's Electrical Engineering department. For the first few weeks, we did nothing but brainstorm for ideas. Our first proposal was a solar power supply for laptops to be used during camping/beach trips. Unfortunately, it was determined that the size and weight of such a contraption would be impractical, and our solar panel simply couldn't produce the wattage necessary to power a laptop. After several other scrapped ideas, we settled on the wackiest one of all: a solar-tracking power supply for a mobile unit (**Figure 1**); a device that not only provides power to sustain its

■ FIGURE 2. A labyrinth toy.

own functions (tracking the sun for optimal energy collection), but also for propulsion and steering of an unmanned vehicle. Fortunately, we didn't have to design the mobile unit. We only had to design the solar tracker, with the provision that it have enough energy left over (stored in a battery) so that it could power a mobile unit.

■ FIGURE 1. SolarTracker on my robotics shop (i.e., basement) workbench.

DECISIONS, DECISIONS

It was the intent of this course to give us a taste of real-world engineering; as such, all decisions were based upon things such as safety, cost, manufacturability, power consumption, component strengths/weaknesses, and impact on the environment. In order to quantify these multiple factors, engineers use a tool called a decision matrix — nothing more than a chart which uses weighted values to compare the merits of different candidate solutions to a problem. All of the weighted values are tallied, and the candidate with the highest total wins.

For example, we had to select an actuator to position the solar panel so that maximum surface area faced the sun. What kind of actuators should we use: stepper motors, servos, or regular DC motors? I was biased toward steppers because I'm a big nerd and had already spent a lot of my own spare time (more than I care to admit) designing a stepper motor driver and really wanted to implement it. But were stepper motors really the best solution for this project? Having never used servos before, we researched them extensively.

Many tests were run on all three candidates. Our solar panel only produced 20 watts of energy, so actuator power consumption was heavily weighted. Torque and accurate positioning were also paramount. As it turned out — much to my dismay — servos were determined to be the best candidate solution. They are internally geared down, providing adequate torque to move the solar panel. Servos also have internal circuitry which provides negative feedback for accurate positioning — saving us from having to design an external feedback device (such as an optical encoder). They also consume less power than stepper motors. So, though I didn't get to use my custom stepper motor driver, I did learn a lot about servos.

Decision matrixes were also used to determine the best mechanism for positioning the solar panel. We considered moving a big lens to focus the sun's rays on the panel. This method would have focused a lot of sunlight (solar energy) on a small fraction of the solar panel's surface, but would the increased local power density be worth the unused real estate? We also considered pivoting the panel on the end of a rod, which came to be termed the "joystick" method. We finally settled on using a frame-in-a-frame method, like the old labyrinth toy (**Figure 2**). This provided two axes of motion and the simplest mechanical design.

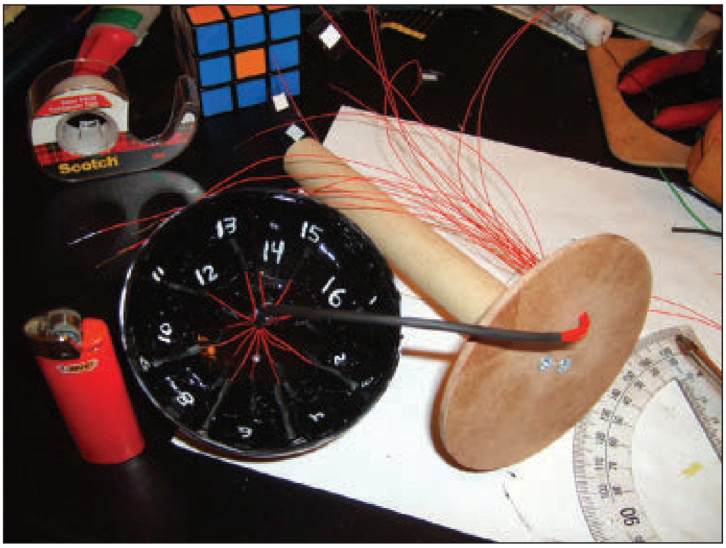
After months of decision matrixes, Gantt charts, and lots of other boring stuff, we were finally ready for the fun part — prototyping!

West Virginia University Institute of Technology

If you are interested in studying engineering, I personally recommend WVU Tech! In 2007, WVU Tech was named as one of the nation's top 100 Undergraduate Engineering Programs by *US News and World Report*. With an enrollment of only 1,452, the faculty/student ratio is very low — which means a lot of individual attention.

THE "BUG EYE"

Okay, remember the three basic elements of a good, interactive machine that I mentioned earlier: input, processing, and output? Think about it like this. Say you want to pick up an apple. First, you look around (input). Light is reflected off of everything around you and into



■ FIGURE 3. Inside the BugEye with its "optical nerve" wires.

your eyes. Your retinas receive the light and send electrical impulses to your brain, which interprets those signals allowing you to locate the apple (processing). Your brain then sends electrical impulses to your muscles, directing your hand to pick up the apple (output).

We started by designing an input device. How do you make a machine look for the sun? Why not build an analog eye (**Figure 3**)? We constructed a four inch diameter semi-spherical plastic dome with an array of 16 phototransistors evenly spaced about its surface (**Figure 4**). It appeared to be a multi-faceted bug eye, so that's what we called it! Each of the 16 phototransistors was placed in series with a 330 ohm resistor between +5 volts and ground, creating 16 voltage divider circuits.

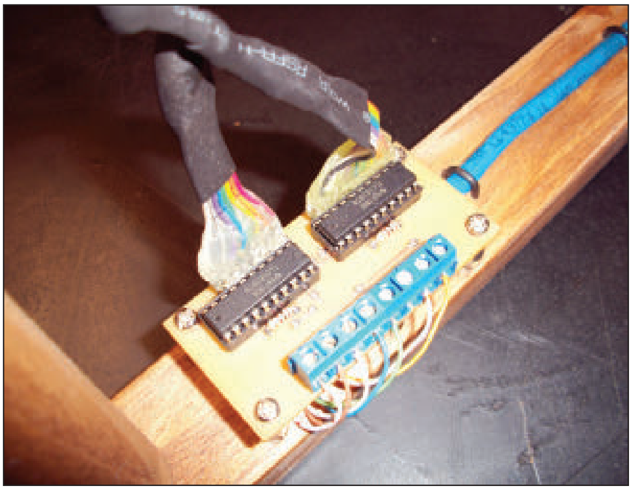
■ FIGURE 4. The completed BugEye and Analog-to-Digital Converter (ADC) circuit.

A voltage divider works using two parts: a fixed resistance (330 ohms) and a variable resistance (phototransistor). As any one phototransistor is exposed to light, a tiny current is produced at its base which causes an even greater current to flow from its collector to emitter. The more light focused directly at the phototransistor, the more collector current will flow. As the collector current increases, so does the voltage drop across the fixed 330 ohm resistor.

There is only a total of +5 volts to be split between the resistor and phototransistor; so as more voltage drops across the fixed resistor, the greater the voltage drop ratio of resistor to phototransistor. This provides an analog measure of the amount of light that any one phototransistor sees. The area of the bug eye experiencing the greatest fixed-resistor voltage drops is the area hit most directly by the sun. That is how a machine looks for the sun!

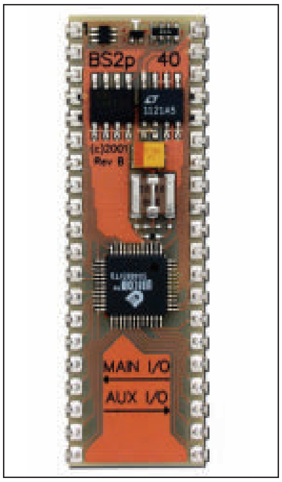
COVERING NEW GROUND

Uh-oh! Problem: The bug eye was speaking one language (analog), but the microprocessor only spoke digital! What we needed was a translator between them — an analog-to-digital converter (ADC) (**Figure 5**). This also posed another problem: serial communication — the way that the ADC and microprocessor talk to each other (something I knew nothing about!). Adam, wishing to avoid learning a new microprocessor and programming language, chose to go with the Parallax BASIC Stamp II (BS2p40) (**Figure 6**). He had used it before and was familiar with it. I, on the other hand, had never used a BASIC Stamp; as the electronics buff of this group, I would have to do a bit of programming while prototyping the circuitry. So, there I was trying to make an "eye" and a "brain" communicate, and I knew nothing about analog-to-digital converters, BASIC Stamps, or serial communication. Talk about a learning curve!



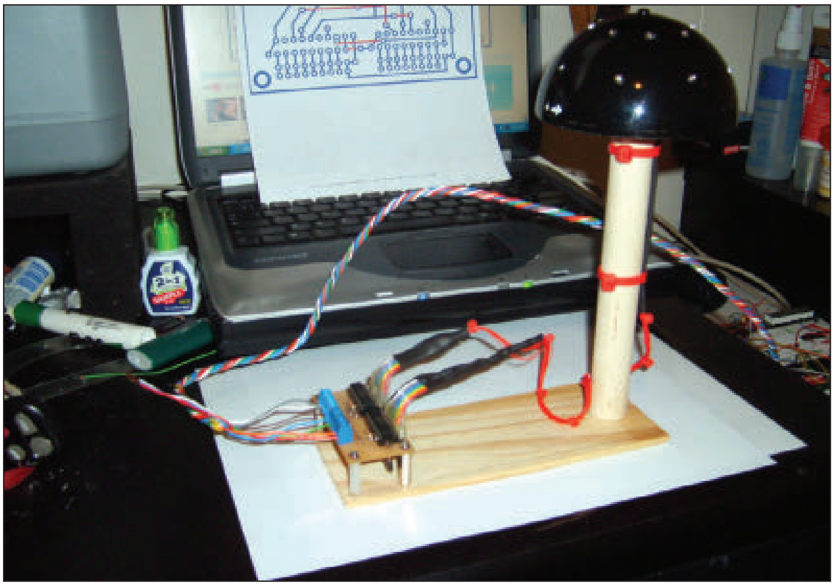
■ FIGURE 5. Two TLC0838CN 8-bit, 8 channel ADC chips on a homemade printed circuit board.

■ FIGURE 6. A Parallax Basic Stamp II with 40 pins (BS2p40).



First, I played around with the BS2p40, quickly and easily learning how to program it (a heartfelt thank you to Parallax for such good documentation!). Then, I studied the eight-bit ADC's datasheets at length, specifically the timing diagram. Once I understood what all of the pins were for and exactly when to set/clear certain bits, I was ready to tackle serial communication.

I wrote a few simple programs, bit-banging (sending one bit at a time) serially between the ADC and BS2p40. With a little troubleshooting, I realized that serial communication isn't really that complicated. It's nothing more than sending a stream of 0s and 1s one after another. The only tricky part is getting the timing issues right and the setup, start, and stop bits. I also discovered the SERIN (SERial IN) and SEROUT (SERial OUT) serial communication commands make the code much simpler (rather than bit-banging). It worked beautifully (**Figure 7**)!



■ FIGURE 7. Prototype of BugEye and ADC circuit.

Depending upon how much light hit a phototransistor, a certain analog voltage would be measured on one of the 16 channels of the two ADCs. A binary (or digital) representation of that analog voltage would then be sent serially from the ADC to the BS2p40. The Stamp polled each of the 16 channels sequentially, stored their values, and then compared them to find the three greatest binary numbers ranging from 0 to 255. Why 0 to 255? Eight bits imply a resolution of 2^8 or 256 values. The three phototransistors with the largest voltage drops (and corresponding binary numbers) must therefore be the three pointed most directly toward the sun. And with that data, we knew the location of the light source.

■ FIGURE 8. Solar Tracker coming together in the WVU Tech machine shop.

POSITIONING METHODS

By this point, we had taken care of all the input and a third of the processing. Now we needed to interpret the data from the sensors and figure out how to make the servos position the solar panel facing the sun. So, how do you map a semi-spherical 16-point array onto a two-axis pan and tilt mechanism? We had to tell each of the servos exactly where to turn, so the resulting normal vector pointed in the direction of the sun.

Adam started out with a really complicated neural networking scheme which would have given us amazing results. But due to the complexity of the neural network and project time constraints, Adam decided to water it down to the "triangle" method. In this method, he would program the BS2p40 to identify the brightest three phototransistors and calculate a weighted average based on their values. That would give him a point somewhere inside the triangle as a target for the panel. Unfortunately, graduation day was fast approaching, and time was running short. At the last minute, he ditched that method, as well. He finally calculated the servo positions (and their corresponding frequencies) for the midpoints of each triangle. This wasn't as flexible as neural networking or weighted averaging, but it did the job.

NO REST FOR THE NERDY

During that last semester at WVU Tech, I probably got an average of two hours of sleep per night. I spent nearly every night (until the break of dawn) in the machine shop

In the process of writing this article, I was asked why we didn't use linear actuators. To tell the truth, we hadn't even considered it. A rotary actuator with spur and pinion gears requires constant power to hold a fixed position, whereas a linear actuator with a screw or worm gear can hold its position without being energized — thereby consuming less power. Linear actuators might have been a good solution!

(**Figure 8**). Whenever my mind was free to wander throughout the day, I thought about this project. I rolled ideas round and round in my head, contemplating my designs from every conceivable angle. I was looking for flaws and trying to figure out the order of construction. Anyone who has ever designed a complicated machine knows that the order of construction must be strategically planned — lest you make a permanent, irreversible move only to realize that you should have done something else first. It's agonizing, yet euphoric at the same time! It is creation, and it is wonderful; there is no better feeling!

THE MOMENT OF TRUTH

The three of us stayed up the entire night before the big presentation. An erroneous line of PBasic code pushed one of our servos beyond its mechanical limits, stripping the gears inside. Mike and I had to drive an hour away to pick up a replacement servo while Adam furiously rushed to complete the computer code. When we finally finished the solar tracker — just an hour before the presentation — we were exhausted! After showers and a quick change of clothes, we made a mad dash for the engineering building.

There we stood in front of a classroom full of professors and fellow students, waiting to be judged. It was the moment of truth, the culmination of seven months of hard work — and supposedly the crowning achievement of our college educations. We each took turns telling about the different aspects of the project, all the while wondering if it would work at the crucial moment. Then, with mounting tension and nervous trepidation, I flicked on the power switch! For a moment, there was nothing but silence as the entire room looked on in wide-eyed anticipation. Then suddenly, as all the air in the room seemed to be sucked up in one collective gasp, it jerked to life and smoothly positioned itself toward the light source (an incandescent flood lamp). It worked!!! I think that Adam, Mike, and I were just as shocked as everyone else.

We received many questions and compliments. Though bulky, heavy, and not nearly as efficient as it could have been, it worked! We each received an A in the course. When Dr. Goodman told me that this solar tracker was the quintessential Senior Design project, I felt that all

Binary Numbers

The numbers that we use every day (0 - 9 or some combination thereof) are part of the decimal number system. Computers use the binary number system (0 and 1) because their transistor logic gates have two states: off and on. Computers represent decimal numbers as a string of zeros and ones.

Say, for example, that one of the Bug Eye's light sensor voltage divider circuits is measuring 2.7 volts. The microprocessor (BS2p40) doesn't understand 2s and 7s, only 0s and 1s. So, the analog voltage (2.7V) has to be converted to a binary (or digital) representation for the computer to understand.

Here's how to make the conversion yourself: That's 2.7 volts out of a maximum five volt reference; 2.7 divided by 5 equals 0.54 or 54%. Since we used eight-bit analog-to-digital converters, that means that the resolution of the binary value is 2^8 or 2x2x2x2x2x2x2x2 or 256 (values 0 - 255). Now, 54% of 256 is 138, but we say 137 since we're starting at 0 instead of 1.

So, now we have a prorated value of 137 out of 256 (the same ratio as 2.7 out of 5). Next, we represent the decimal number 137 in binary form; 137 in decimal equals 10001001 in binary. Notice the decending powers of two below.

(2^7)x1 + (2^6)x0 + (2^5)x0 + (2^4)x0 + (2^3)x1 + (2^2)x0 + (2^1)x0 + (2^0)x1 = 137

(128)x1 + (64)x0 + (32)x0 + (16)x0 + (8)x1 + (4)x0 + (2)x0 + (1)x1 = 137

(128)x1 + 0 + 0 + 0 + (8)x1 + 0 + 0 + (1)x1 = 137

128 + 0 + 0 + 0 + 8 + 0 + 0 + 1 = 137

128 + 8 + 1 = 137

10001001 (binary) = 137 (decimal)

Therefore, the microprocessor now understands 10001001 to mean 2.7 volts (or a little more than half of the five volt reference) is being measured by that particular light sensor. After polling the other 15 light sensor circuits, the computer can compare the binary representations of those voltages and decide which three are seeing the most light — and therefore determine in which direction the sun is located.

of our hard work had paid off.

Six months after graduation, I borrowed the solar tracker from WVU Tech's Electrical Engineering department and made several modifications. I recessed the microprocessor inside the base with a glass cover plate to protect it from dust (**Figure 9**). I added a power connector and voltage regulator, so that the tracker could be powered from a wall wart (for repeated indoor demonstrations and resulting lack of solar charging). I made the bug eye's arm retractable for ease of transit and storage. And finally, I sanded, stained, and polyurethaned the solar tracker for a high gloss shine. If this device was going to be my legacy at WVU Tech, I wanted it not only to work but also look nice (**Figure 10**)!

FINAL THOUGHTS

I have come a long way in my pursuit of robotic/electronic knowledge, and I realize that I have merely scratched the surface. For every success that I enjoy, there have been many hundreds of miserable failures. If you are new to electronics and have an intense desire to learn, then DO NOT GIVE UP — EVER!!! After years of midnight tinkering and scores of mind-numbing boring books, I am finally starting to get this stuff. New and wonderful possibilities are presenting themselves to me, and it is an amazing feeling!

If you are interested in building a solar tracker of your own, visit **www.nutsvolts.com** for block diagrams, wiring diagrams, schematics, datasheets, parts lists, and code. Feel free to contact me at samuelaaronward @gmail.com. **NV**

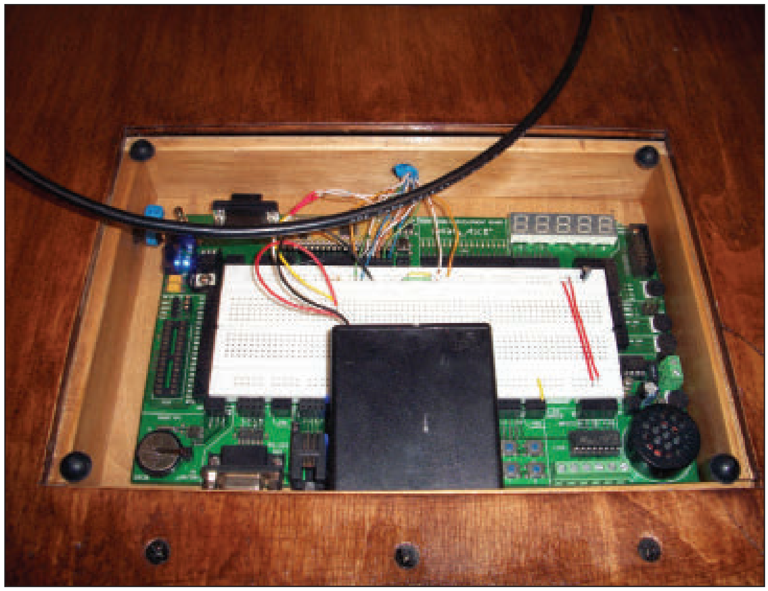
RESOURCES

Parallax
www.parallax.com

Solar Tracker Video
www.youtube.com/SamuelAaronWard

West Virginia Robotics Club
www.wvrc.us

West Virginia University Institute of Technology
www.wvutech.edu



■ FIGURE 9. Glass cover plate over recessed BS2p40 microcontroller board.

■ FIGURE 10. Finished SolarTracker after some modifications in January 2009.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- ✔ High Current, Low Voltage Amp
- ✔ Time Delay Circuit

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

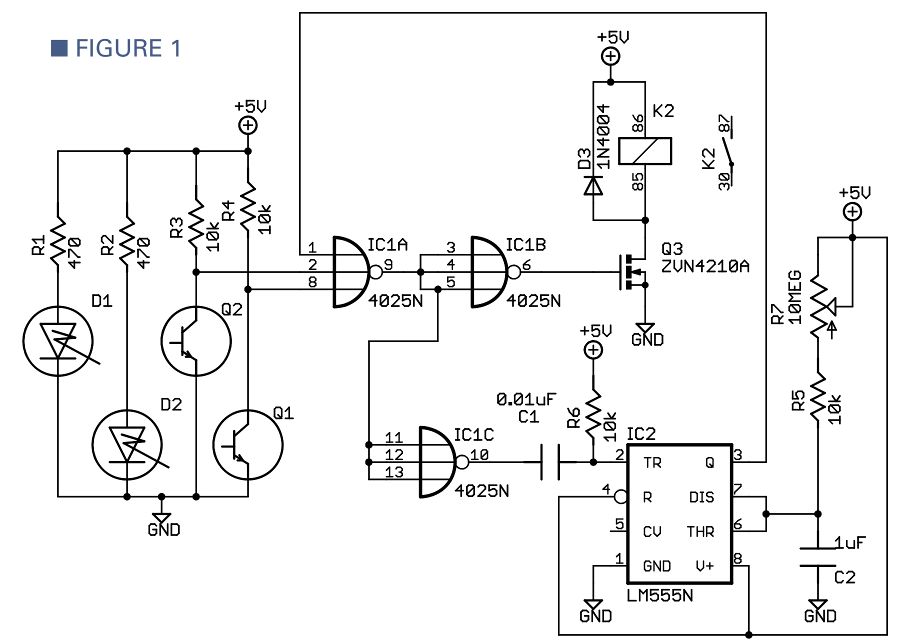
TIMER

Q I need your help. I am working with a photocell and 555 timer circuits on a model train platform. I haven't been able to get the correct response from the circuits. That's why I need your professional help. When the train breaks the light beam, I need a relay to energize; after the train passes and the photo cell detects light, I need a timer to time out and give me about two to 10 seconds before the relay de-energizes and returns to its original state.

— John S. Mitterer

A I actually answered this question last month with a PIC micro solution, but Mr. Mitterer would rather have a discreet part solution, so here it is: In the circuit in **Figure 1**, there are two opto sensors because the crack between cars would cause a glitch with only one. The two sensors are placed such that one is always blocking the beam while the train is passing. When the first beam is broken, its output goes high, energizing the relay. When both sensors are lighted, the output of IC1A goes high, triggering the 555 one shot. The 555 output goes high holding the relay energized for the time delay. The mechanical inertia of the relay should keep it closed, but if it glitches due to the delay in going around the 555 loop, add about 1,000 pF to ground from Q3 gate to slow it down. The circuit will work at 12 volts with appropriate change in relay and R1, R2. **Figure 2** shows the Parts List.

■ FIGURE 1



CHICKEN COOP DOOR CONTROL

Q I was trying to follow a thread of information on the Web about timed chicken coop door design and construction, and I wonder if it is you who might know about this. Particularly, I would like to use a small solar panel to power the motor that opens the door. Currently, I use a small solar panel to power the electric fence on the farm. In general, I am not very knowledgeable about these things and I wonder if this can be done.

— Mark Maggio

A I answered a question like this before, but it deserves another look. You will need a battery to power the motor on cloudy days and when the sun goes down. The relay I chose draws 34 milliamps, and over the day will use about 1/2 amp-hour, so a battery of 2 or 3 Ah should be used in case of several cloudy days. I lost 15 chickens in one night because I

forgot to close the door; so you do not want to run out of power. I put Jameco part numbers on the schematic (**Figure 3**). The solar panel is only rated for 100 mA, which is not enough to keep the battery charged, so either parallel several or look for a more robust panel. I put in R1 in case Q1 does not want to turn off at dark. The lower switch (SW1) will open when the door is closed, stopping the motor. SW2 stops the motor when the door is fully open. I leave the mechanics up to you.

■ FIGURE 2

TRAIN DETECTOR PARTS LIST

PART	DESCRIPTION	PART NUMBER	SUPPLIER
D1, D2, Q1, Q2	IR XMTR & DETECTOR	276-142	RADIOSHACK
IC1	TRIPLE 3 INPUT NOR	676001	JAMECO
IC2	555 TIMER	27422	JAMECO
K2	RELAY, 5V, 500 OHM, 0.5 AMP	106462	JAMECO
Q3	MOSFET, LOGIC LEVEL ZVN4210A OR 2N7000	119423	JAMECO
R7	5MEG POT	RV24A-10-15R1-B505	JAMECO
D3	GEN. PURP. 1N4004	35991	JAMECO
C1	0.01 µF, 10%, 50V	5444833	JAMECO
C2	1 µF, 10%, 50V	527945	JAMECO
R1, R2	470 OHM, 5%, 1/4 W	690785	JAMECO
R3, R4, R5, R6	10K, 5%, 1/4 W	691104	JAMECO

HIGH CURRENT, LOW VOLTAGE AMPLIFIER

Q I want to drive some motors very slowly but at high torque. It's for a motion control system. I don't want to use a geared motor because the gears introduce backlash. I want to use direct drive, but I would not like any switching driver solution because they radiate RFI which causes all sorts of problems. So, what I'm asking for is a linear amplifier, good from DC to maybe 10 Hz (responding faster would be fine but the control signals change very slowly) that has a voltage gain of maybe a half. I intend to run it from an op-amp — a TL082 — swinging the input signal roughly ±10 VDC and a current gain of about a thousand: 10 mA in and 10A out from ±5 VDC rails. I guess I need a linear amplifier that works at DC; preferably with some current limit so I can do the "screwdriver test" — throw a screwdriver across the output terminals and it just keeps working (getting hot but still working). I'm aware that linear amplifiers are woefully inefficient and that I'll need lots of big transistors and heatsinks, and probably a fan or three, but I'm fine with that.

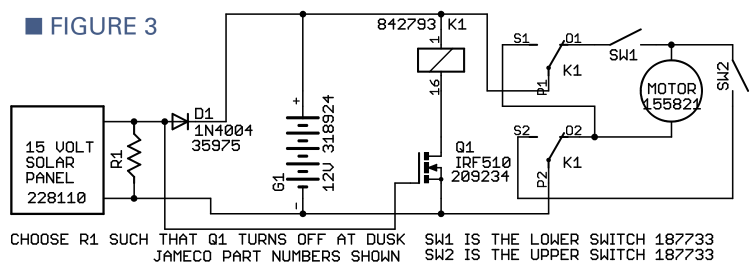
Currently I have a lashup that works, using National Semiconductor's LM12 power op-amps, but they dissipate even more power than they need to, because they won't even start working before about 15V, are awkward to mount (a four-pin TO-3!), and those parts are now obsolete and the price is skyrocketing. Can you help me?

— Anonymous

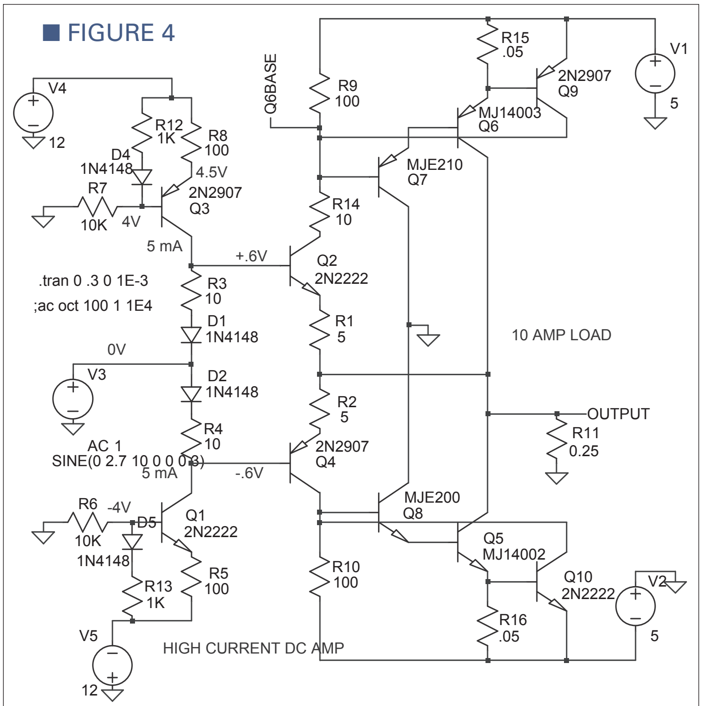
A I recently designed a similar amplifier; it was for ±200 volts output but should work at lower voltages (see **Figure 4**). The transistors Q1 and Q3 are current sources to provide bias and to maximize the input impedance (it's about 30K). The amplifier is unity gain and is intended to be class B; the current through Q1 and Q2 is 10 mA which gives a one volt drop across R9 and R10. That is not enough to turn on the output transistors but the simulator shows 10 mA DC current through Q5 and Q6, and there is no crossover distortion. Instead of using a Darlington at the output, I connected Q7 and Q8 collectors to ground in order to minimize the Vsat of the output. The drop across the current sensing resistors, R15 and R16, and Vsat limits the output to 2.5 volts at 10 amps.

Without the current limit, you could get two volts at 40 amps or three volts at 10 amps for output. In any case, the output into a short circuit — without current limit — will not exceed 50 amps and the amplifier should survive

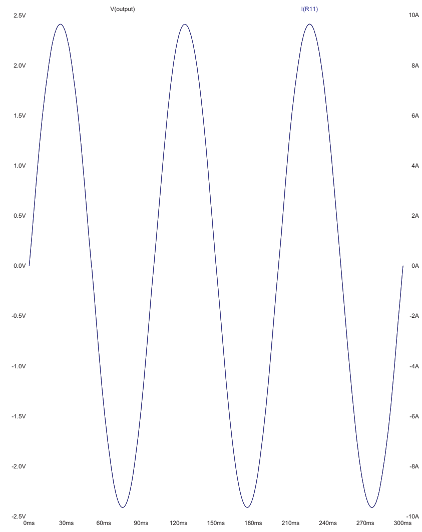
■ FIGURE 3



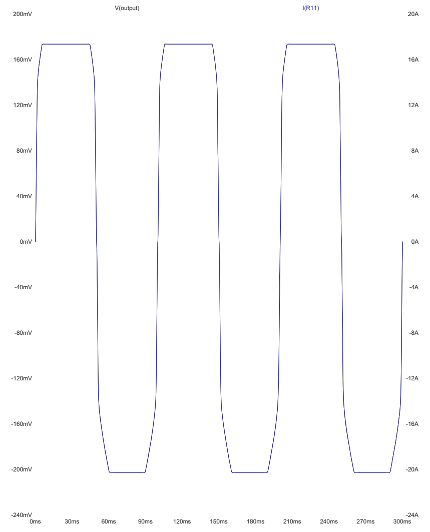
■ FIGURE 4



■ FIGURE 5



■ FIGURE 6



that if there is enough heatsink. Wakefield heatsink 421-K should work without a fan for your normal load.

Figure 5 shows the normal output with 0.25 ohms load and **Figure 6** is the short circuit (0.01 ohms load) output. The frequency response is down 1.5 dB at 100 kHz.

AUDIO COMB FILTER

Q I need a comb filter in the audio range (100 Hz to 4 kHz). The channel to channel attenuation should be as high as practical. Can one bandpass filter be designed using plug-in values?

— Craig Kendrick Sellen

A I suggest 1/2 octave bandpass filters from 150 Hz to 3 kHz. The octaves will be 150-300, 300-600, 600-1200, 1200-2400, and 2400-4800. In order to limit the channels to eight, I dropped the first and last 1/2 octave, so the first filter is 212-300 and the last is 2400-3390 Hz.

Figure 7 is the basic filter. It is a two-stage (four pole) Butterworth bandpass with 0.25 dB at the band edge. The channel to channel attenuation is only 3 dB (0.707 amplitude; see **Figure 8**), so I assume you would want to cascade another two stages to get 6 dB (0.5 amplitude) channel to channel (see **Figure 9**). You will gain 3 dB with each two-stage section that is cascaded. I only show four channels in Figures 8 and 9 because getting eight channels into the simulator is tedious and I am not sure the simulator could handle it. **Figure 10** is a table of R-C values for the eight channels.

PWM MOTOR NOISE

Q After trying two different motor control circuits published in *Nuts & Volts* with less than the results I desired, I put together a circuit using a 556 and power transistor switch. I have used it for two years on a fishing rod winder (for rod building) and it has been quite reliable. I have a question on an undesirable aspect of using a PWM control that I hope you will see fit to answer or direct me to a solution.

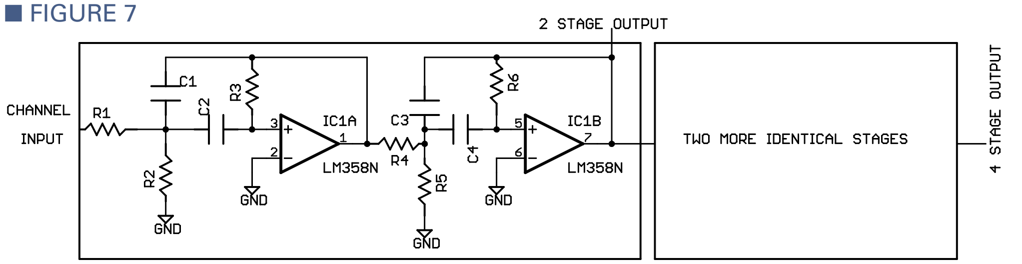
1. High whine noise: The motor emits a high whine that is disconcerting at times when operating the rod winder. I am using a two-speed automotive 12V windshield motor (surplus) that has output speeds of 45 RPM and 105 RPM. The noise is similar to that heard from stepping motors. The motor is isolated mechanically from the rod winder shaft by the mount and the use of a flex coupling so that less noise is transmitted from the motor. The whine noise drops off drastically when the speed is below 30%. I have tried several different base frequencies of the first stage of the LM556C and found that the frequency I have set (800 Hz) works best. When the frequency is lower, the noise is less but the motion of the output shaft is jerky such as with a stepper motor at very low speeds. At the frequency used, the motion is smooth. At higher frequencies, the noise intensifies. Once the motor is started above 30%, the speed can be backed off to as low as 2-4 RPM. The other circuits tested would not go below about 50% and this is a big reason to use this circuit. Above about 60%, there is a second higher pitched harmonic that becomes equal in intensity.

Can the noise of the motor be reduced to a more acceptable level without sound isolating it? The heat output is acceptable even running for 4-6 hours continuously. Enclosing would raise the heat level and require a fan.

— G. Bates

A I can think of two solutions: 1. Operate at a frequency above

■ FIGURE 7



your range of hearing. 2. Put a capacitor of about 2,500 µF to 3,000 µF from Q drain to source. That will reduce the pulse amplitude and reduce the noise.

If stiction is a problem (the motor doesn't start moving until the voltage is more than needed for the speed), then you need some feedback. One way to do that is to monitor the motor voltage while it is not being pulsed. The motor is also a generator whose voltage is proportional to speed.

FIGURE 8

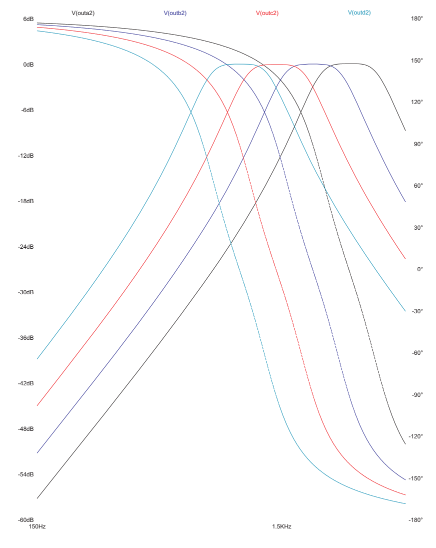
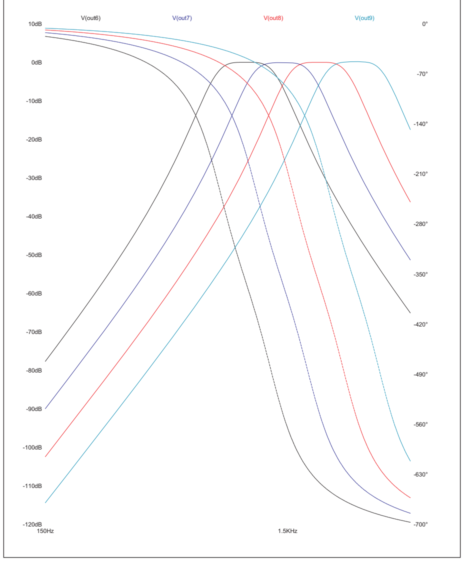


FIGURE 9



TIME DELAY

Q In my model railroad layout, I need a time delay of 10 to 15 seconds. This is the application: A trolley enters a tunnel with a green signal. A reed switch picks up a relay and stays closed through its own contact and starts a time delay. After the time delay, the relay will reverse the trolley and change the signal to red. The available power is 12 volts DC and the relay load is maximum two amps.

— Ted Asousa

A For this type of delay, a 556 dual timer is appropriate. The first timer does the delay and the second energizes the relay. In the circuit in Figure 11, I have direct connected the output of the first timer to the trigger of the second, so it is continuously triggered and the output will remain high as long as the timer is powered.

I have gratuitously included the relay connections to reverse the trolley and change the signal light.

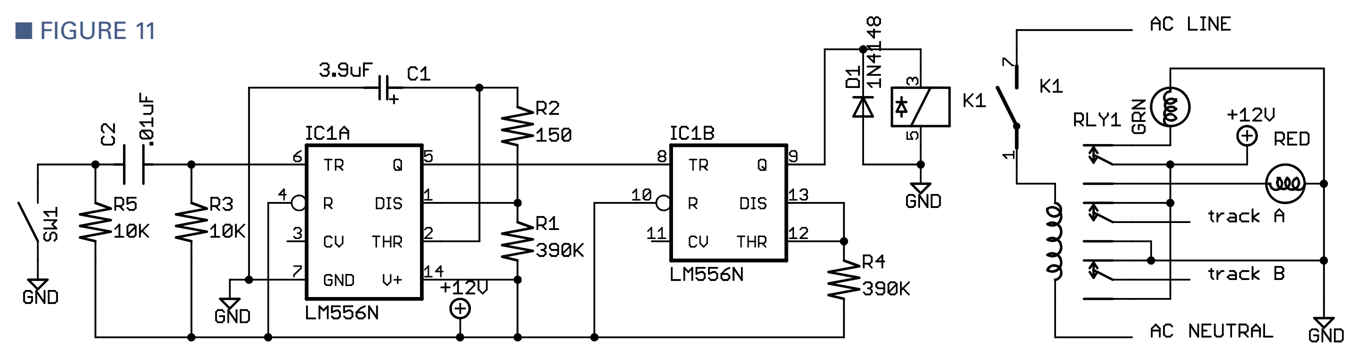
The input trigger is a switch closure. Momentary closure of S1 will cause K1 contacts to open for 15 seconds, then close until the next closure of S1. Mouser does not list a 12 volt DC 3 PDT relay, so I selected a 115 VAC relay and a SPST 12 volt DC relay to operate it.

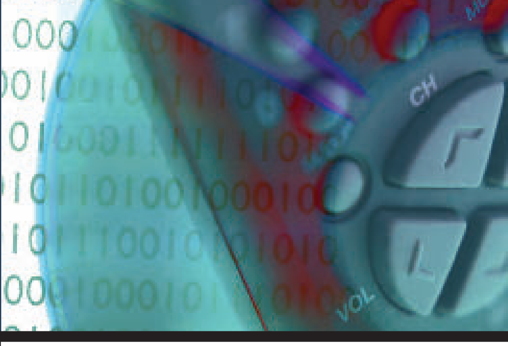
The Mouser part number for K1 is: 551-EQ1-221115; $1.68. RLY1 part number is: 769-HC3-H-AC115V-F; $10.80. The part number for the 556 is: 512-lm556CN; $0.50. A socket is available for RLY1, part number 769-HC3-PS-K; $1.56. **NV**

EIGHT CHANNEL COMPONENT VALUES — FIGURE 10

	212-300 HZ	300-424 HZ	424-600 HZ	600-849 HZ	848-1200 HZ	1200-1700	1700-2400	2400-3390
R1	69.1K	49.1K	34.6K	24.4K	17.4K	122K	87.1K	61.6K
R2	14.3K	10.1K	7140	5050	3560	25.3K	17.7K	12.6K
R3	202K	143K	101K	71.4K	50.7K	355K	254K	180K
C1, C2	10nF	10nF	10nF	10nF	10nF	1nF	1nF	1nF
R4	115K	81.6K	57.6K	40.7K	28.8K	203K	144K	102K
R5	23.8K	16.7K	11.9K	8400	5910	42.2K	29.4K	20.9K
R6	336K	238K	168K	119K	84.2K	593K	422K	298K
C3, C4	10nF	10nF	10nF	10nF	10nF	1nF	1nF	1nF

FIGURE 11





NEW PRODUCTS

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(1) Terrestrial digital TV broadcast support and HD video playback and recording.

(2) Two camera module interfaces combined with VPU5F and JPU.

(3) High operating frequency of 500 MHz for high performance processing of tasks such as simultaneous two-screen display.

(4) Full complement of high performance peripheral functions for multimedia applications.

A number of system solutions will be made available to help customers shorten development period and reduce system costs, including a reference platform incorporating the SH-MobileR2R and a graphics library that supports the functions of the 2-D graphics accelerator.

The reference platform makes it possible to study system functions, evaluate performance, and develop software efficiently. The graphics library conforms to the GDI-Sub*11 specification, which supports Windows® Automotive 5.0*12 Service Pack 2 from Microsoft Corporation, enabling customers to realize a wide variety of map rendering functions using the 2-D graphics accelerator.

There are also plans to provide support packages for IP camera devices and the like, including Linux BSPs and video codec middleware.

Two package options are available to enable more compact systems: 449-pin BGA (21 mm × 21 mm, 0.8 mm pin pitch) and 441-pin POP-compatible BGA (14 mm × 14 mm, 0.5 mm pin pitch).

For more information, contact:
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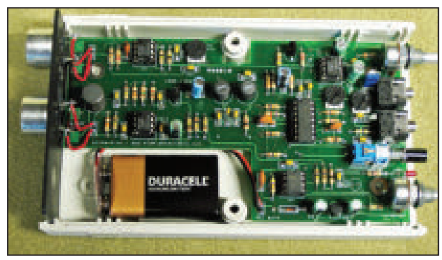
40 kHz ULTRASOUND TRANSCEIVER



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The receiver portion — modeled after their Ultra-RX1 — shifts 35-45 kHz ultrasound down to human hearing and utilizes a 10 kHz wide

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The PCB (5.68 x 3.16 inches) and parts fit in an available plastic clam-shell case (6.161″ L x 3.677″ W x 1.738″ H), along with a 9V battery (not included). Transmit and receive piezo transducers mount on the front panel. The back panel features: frequency tuning pot, power switch with LED, key jack, audio stereo jack, and volume control. The audio jack accepts stereo or mono phones (phones not included). In each assembly section of the included manual, step-by-step instructions are followed by test instructions. A 9V battery and VOM cover a majority and sufficient number of the measurements for success.

For more information, contact:
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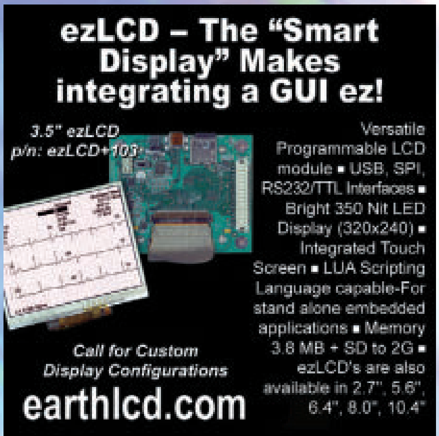
SHOWCASE



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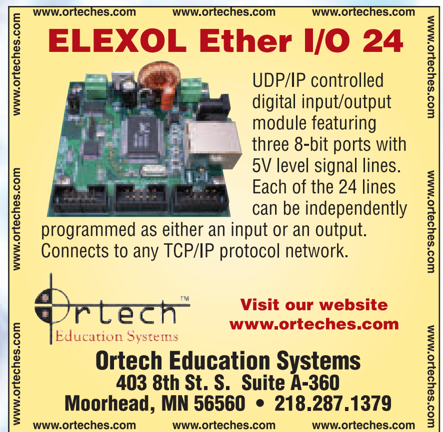

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LIGHTNING SCREEN

This lightning screen project is based on a design created by Kenneth Strickfaden and used by him in many Hollywood horror and science fiction films [Figure 1]. Although it represents a principle of physics centuries old, anyone with a passion for lightning, high voltage phenomena, and electrical history will find this device to be an impressive performer.

By Harry Goldman

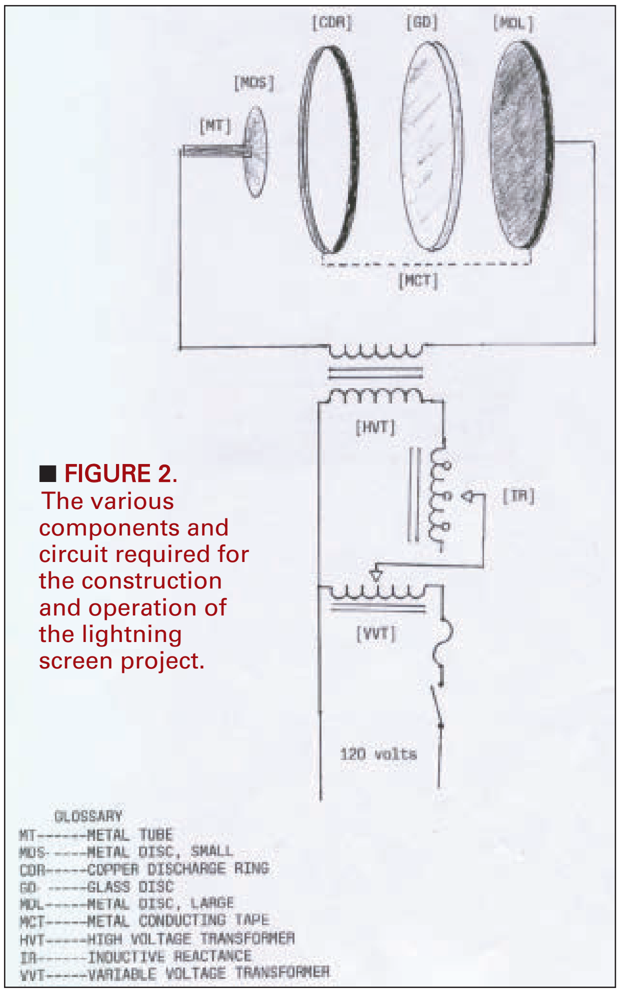
■ FIGURE 1. Kenneth Strickfaden, special electrical effects wizard of Hollywood's golden age, is shown operating the lightning screen used in numerous mad scientist movies.

Technically, it consists of a simple two-plate capacitor made from metal discs with a disc of glass as the dielectric. Think of it as a flattened Leyden jar[1]. The challenging part is not so much electrical as it is in assembling and mounting the components [**Figure 2**].

The large metal disc [MDL], glass disc [GD], and copper discharge ring [CDR] are identical in overall diameter. The smaller metal disc [MDS] is not critical but generally one-third the diameter of the large metal disc. The copper discharge ring is formed from one-quarter inch [ID] or larger tubing. Several short lengths of metallic conducting tape [MCT] — strategically placed at equidistant points — create an electrical connection between the large metal disc and the copper discharge ring.

The power source required is dependent upon the overall dimensions of your project. Large systems demand voltages of 30 kV or up. Smaller projects can function at one-half those potentials. This project is powered by an oil-immersed 65 kV x-ray transformer [**Figure 3**]. However, it will fill the screen with discharges while running at only 50-55% of its rating [**Figure 4**]. The final dimensions of your project will be determined by ambition, imagination, craftsmanship skills, and experience with high voltage electricity. Strickfaden's lightning screens — constructed from discarded and cobbled-up parts — measured approximately 44″ across. The screen for this project is a modest 16″ [OD] for the large discs with a smaller disc of 8″ [**Figure 5**]. Now that I have a feel for what my screen can do, I plan to replace the central disc with one having a 5-6″ cross-section. This change will result in an increase in the sparking distances and with (no doubt) an accompanying rise in the crackling noise levels.

In assembling the material for this project, I followed



■ FIGURE 2. The various components and circuit required for the construction and operation of the lightning screen project.

Strickfaden's practice of searching out ready-made items that might be applied to its construction. The supporting framework used here appears to have previously served as a Lazy Susan food tray. The entire assembly is mounted on a mobile cabinet originally designed for audio equipment. Both the Lazy Susan and equipment cabinet were garage sale purchases. Any craftsman skilled in woodworking will have the tools and expertise to design and fashion their own supporting structures. Plus, we've seen what marvelous structures can be fashioned from PVC pipe.

The metal rod or tube [MT] extending from the small central disc can either be soldered, welded, or bolted in place. I chose the latter by pressing a threaded shaft coupler into one end of the tube and secured it to the disc with a flathead bolt. It was necessary to form a small depression around the disc's center hole so the head of the bolt would be in the same plane with its bottom surface. The small central disc is attached to the glass with double-sided tape. It must be mounted at the exact center of the glass disc. An electrical connection was made using a toggle bolt. Once forced into the tube, the toggle stays fixed by friction. It can be easily removed. The entire screen assembly is held in place with simple retainers of non-conducting materials such as plastic, bakelite, wood, etc. [**Figure 6**].

I found that discharges emanating from the flat center disc show a tendency for hugging to the surface of the glass. This can create enough heat to eventually crack the glass. By substituting a sturdy metal pie, pizza, or dinner plate, the chance of overheating the glass is greatly reduced. The raised "wings" of the plate position the edge or discharge surfaces above the glass.

Heat resistant (tempered) glass is a better choice of material when it comes to lightning screens. Round tempered glass intended for protecting table surfaces can be obtained from your local big box store (Target, etc.). However, you will have to use it in the size at which it comes as tempered glass cannot be cut down to size. If you are thinking of ordering a custom-sized tempered glass product from a local glass firm, brace yourself when the clerk quotes the price. I used 3/16" common glass for the dielectric. Avoid plain windowpane glass.

Discharges between the center disc and the copper ring are not only impressive but also very loud (ear protectors recommended). By again taking a tip from Strickfaden, the effect is further enhanced when coating the large metal disc with a special luminous paint or paper. The sparks will temporarily leave their signature on the luminous material. A self-stick luminous plastic product can be obtained from Extreme Glow, P.O. Box 3037, Tupelo, MS 38803. The USA phone is 1-888-748-4755. Luminous paints are available from any craft or department store. I did not try paints so I am unable to tell you just how well they work in this situation.

The best way to demonstrate the full effect of the discharges is to operate the screen in total or near-total darkness. Short runs not only create the best after-glow effect but reduce the chance of overheating the glass. Long exposures tend to blur the individual lightning trails on the glow product. Interestingly, there is a simple sketch of a lightning screen on page 180 of *Kenneth Strickfaden, Dr. Frankenstein's Electrician* (McFarland, 2005) suggesting the use of a mirror as the dielectric.

To prevent electrical currents from running wild and tripping circuit breakers, an inductive reactance [IR] or choke must be inserted in series with the 120 volt input line of the high voltage transformer [HVT]. I applied a multi-tapped, iron-cored inductor from an old medical machine [**Figure 7**]. The tap measuring 20 mH provided the best results. A simple reactance can be made by packing a one-inch by seven-inch plastic or phenolic tube with soft iron (coat hanger) wire cut to 6" lengths and winding it with no less than two layers of #14 or #16 copper conductor. Give each layer a wrapping of tape before continuing winding. Tapping the ends and center turn of the second layer will provide a choice of reactances [**Figure 8**]. In place of the core of wires, ferrite

■ **FIGURE 3.** The 65 kV (oil immersed) x-ray transformer used to power the lightning screen. An inductive reactance is hooked in series to limit the current draw.

FIGURE 4. The lightning screen's discharges are not only impressive but very loud.

■ **FIGURE 5.** The completed lightning screen project.

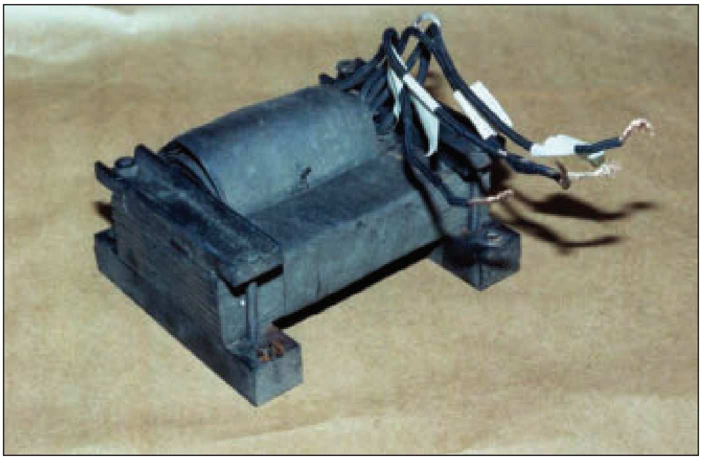
■ **FIGURE 6.** A close-up showing comparative sizes of the 16″ and 8″ discs. Also shown are plastic retaining clips to hold the disc in place. The luminous glow paper behind the glass disc provides the coloration.

rings can provide the electrical tinker with a superior inductor core product.

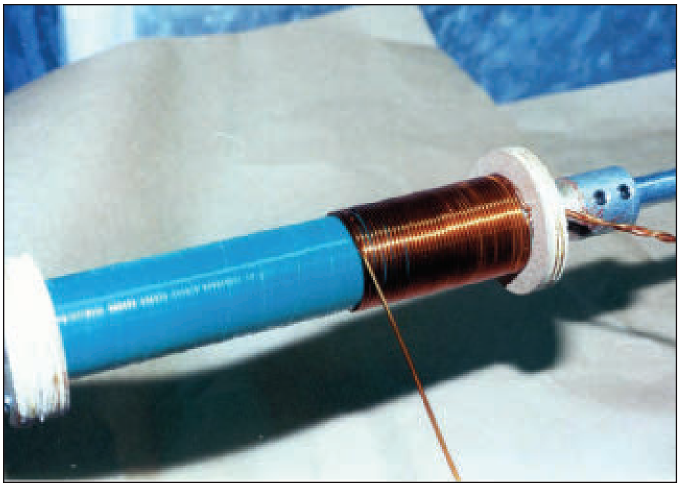
A simpler and less time-consuming method is to connect a 150 watt (or larger) incandescent bulb in series with the transformer input line. Another approach is to insert an electrical heating device (hot plate, toaster, etc.) or similar resistance in the circuit to act as a ballast. My project pulls between 5-7 amperes. No current control is required when screens are powered by current limiting ignition or neon sign transformers.

A piece of equipment not essential to the construction of a lightning screen — but which is highly recommended for its operation — is a variable voltage transformer [VVT] such as a variac, powerstat, etc. The VVT allows full control over operation of the screen and can assist in determining the correct amount of ballast. Too much ballast draws a near-zero current and produces very little sparking. A weak ballast will fill the screen with crackling discharges but at the expense of pulling an excessive current. The VVT allows the operator to find an acceptable balance. Lacking such a control requires energizing the circuit at full voltage. Although this procedure can create startling results, it is a practice I choose to avoid.

Variable transformers featuring both a voltmeter and ammeter are preferred over the single or non-metered models. Unfortunately, purchasing a dual meter VVT can be an expensive proposition. Even a used double-meter model — if one can be found — brings in big money. I surmounted the problem by purchasing a 7.5 ampere meterless VVT at a hamfest for less than $10. I mounted it within an old metal cabinet and added two inexpensive meters along with an inlet, outlet, switch, fuse, and pilot light, for a cost of less than $50. eBay is another good source for finding used variable transformers.



■ **FIGURE 7.** An inductive reactance was placed in series with the 120 volt line to control current draw. This unit was once a component part of an old medical machine.



■ **FIGURE 8.** An inductive reactance can be easily constructed using readily-available materials.

Finally, the lightning screen should not be confused with the safe, silent, plasma-like luminous discs which have become popular sales items at variety stores. On the contrary, the project described herein involves electrical potentials which are unforgiving to those who become careless in its operation. The good news is that the lightning screen is an alternating current capacitor with little — if any — residual charge remaining on the plates once it is shut down. Even so, experimenters must disconnect it from the power line when it becomes necessary to make adjustments or when not in use.

A remarkable person once declared, "No man is an island unto himself." That statement is certainly true in this endeavor and I gladly acknowledge the valuable input and assistance received from Steve Cole, Mitch Tilbury, and Suzanne Gaeta. **NV**

Footnotes

1) An early form of capacitor invented in 1745 in Leyden [Leiden], The Netherlands.

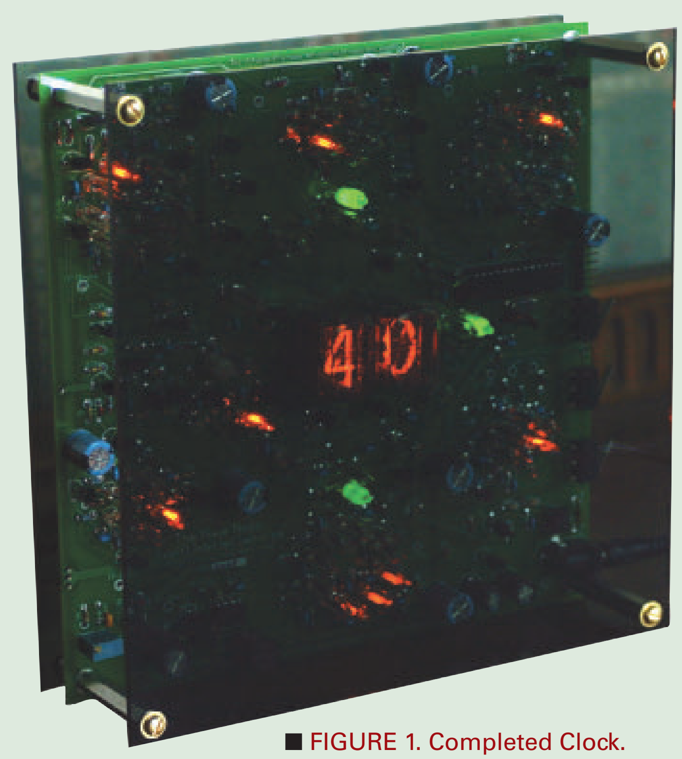
Harry Goldman can be contacted by sending correspondence to
3 Amy Lane, Queensbury, NY 12804.

PARTS LIST

Because of the nature of this project and the spirit in which it is intended, there is no formal parts list. This project can be made from used/collectable parts wherever they may be available, so it is up to the reader to gather the necessary components. Here's a basic list of some of the items I used in my build. The only item I purchased new was the glass disc.

- 3/16" x 16" diameter glass disc
- 65 kV x-ray transformer
- Inductive reactance, 20 mH
- Large metal disc 16" diameter
- Small metal serving dish 8" D
- Metal tube 4 3/4" x 8"
- 1/4" ID copper tubing
- High voltage wire
- Electrical tape
- Cabinet
- Etc., etc., etc.

NIXIENEON CLOCK


■ FIGURE 1. Completed Clock.

The NixieNeon clock is a product of my love for clocks and electronics. Ever since I was a young child, I have been fascinated with electronics. I remember watching my father build nothing boxes with neon bulbs and 90 volt bateries which would make you tingle right up to your elbows when you touched them (bad influence from my older brother). As the years went by, my primary focus shifted to computers and writing software but still, I enjoy the smell of rosin when soldering and enjoy tinkering with small circuits.

BY JOE CROFT

My fascination with clocks was slower to develop. It was awakened when inheriting several very old clocks which were once my grandfather's.

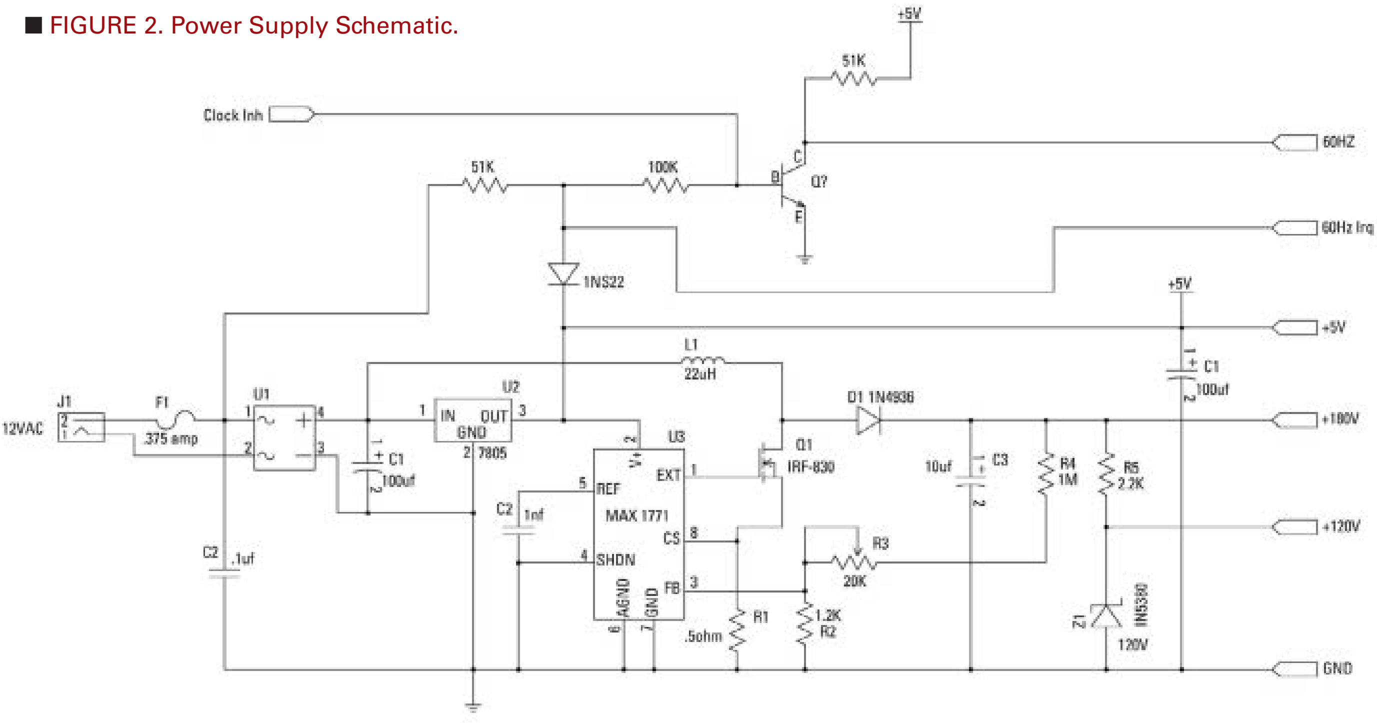
I have wanted a nixie tube clock for some time. In the last few years I decided I would build one, but not just another clock driven by a microcontroller where all of the magic of the time keeping was hidden inside a piece of silicon. I wanted a circuit where I could watch it count, like the old skeleton clocks. Scouring through the Internet, I ran across a circuit using neon lamps in a ring counter which then drove the nixie tubes. At last my break-through — a clock circuit which was as retro as the nixie tubes themselves!

At first, I tried to do it without a processor. This worked well, but it had its limitations. First and foremost, the neon ring counters proved to be somewhat erratic over time. Every so often, a bulb would not fire when it should or — just as bad — one would light when it shouldn't. Either way, this caused the clock to miscount.

After building several clocks of the original design, I decided to add a processor to help hide the occasional miscount; it also helps finding which of the bulbs are misfiring. To maintain the original goal, the processor does not have an active role in the clock's operation. It does track the time and will periodically make the rings 'dance,' then reset the clock to what it has as the correct time. The ring counters still do the bulk of the job. It can also spin individual rings which hopefully will show bad bulbs. Ultimately, I want to have the processor to monitor the rings to detect miscounts.

Developing this clock has proved to be quite the learning experience for me. From it, I have learned that neon ring counters are quite sensitive. Neon bulbs do not have a consistent behavior from bulb to bulb. As well, the bulbs are sensitive to light. I have also found that neon bulbs can be easily stressed by excessive current. Empirically, I have determined even short periods of excessive current can change their trigger voltage. So, be kind to your neon bulbs.

In the end, the biggest lesson I have learned is that time is not on your side with this clock. As the bulbs age, their characteristics change. Over time, there is the good possibility that some bulbs in the clock will not fire or fire when they shouldn't which will cause it to miscount. It's not that the bulbs won't light; they just will not light when they should. For me, I can live with this. The processor will keep the clock on track for the most part. When a bulb is bad enough or is messing up and making the clock get way off, I'll just replace it and wait for the next bulb to misbehave.



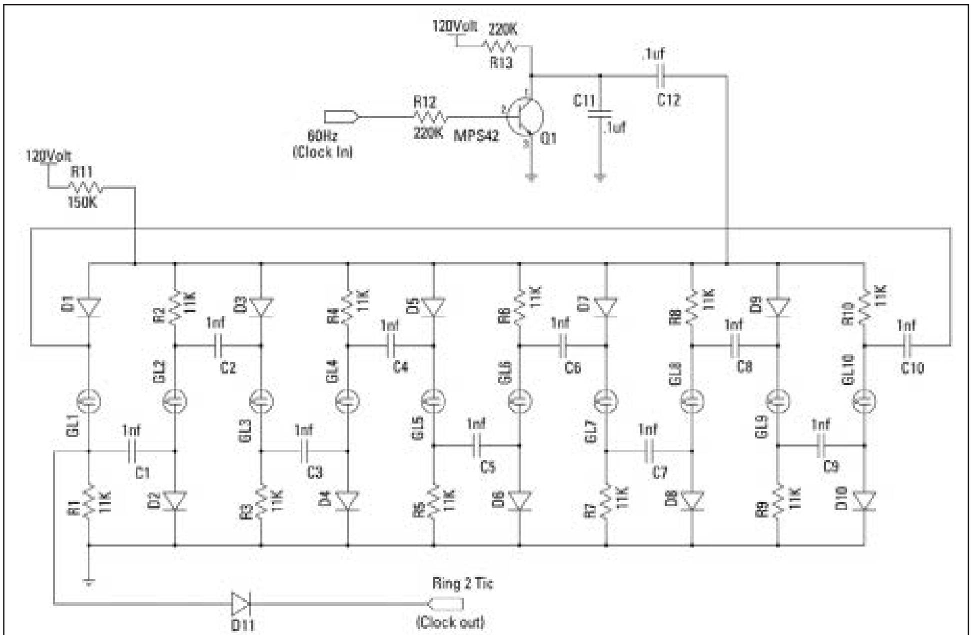
■ FIGURE 2. Power Supply Schematic.

Circuit Description

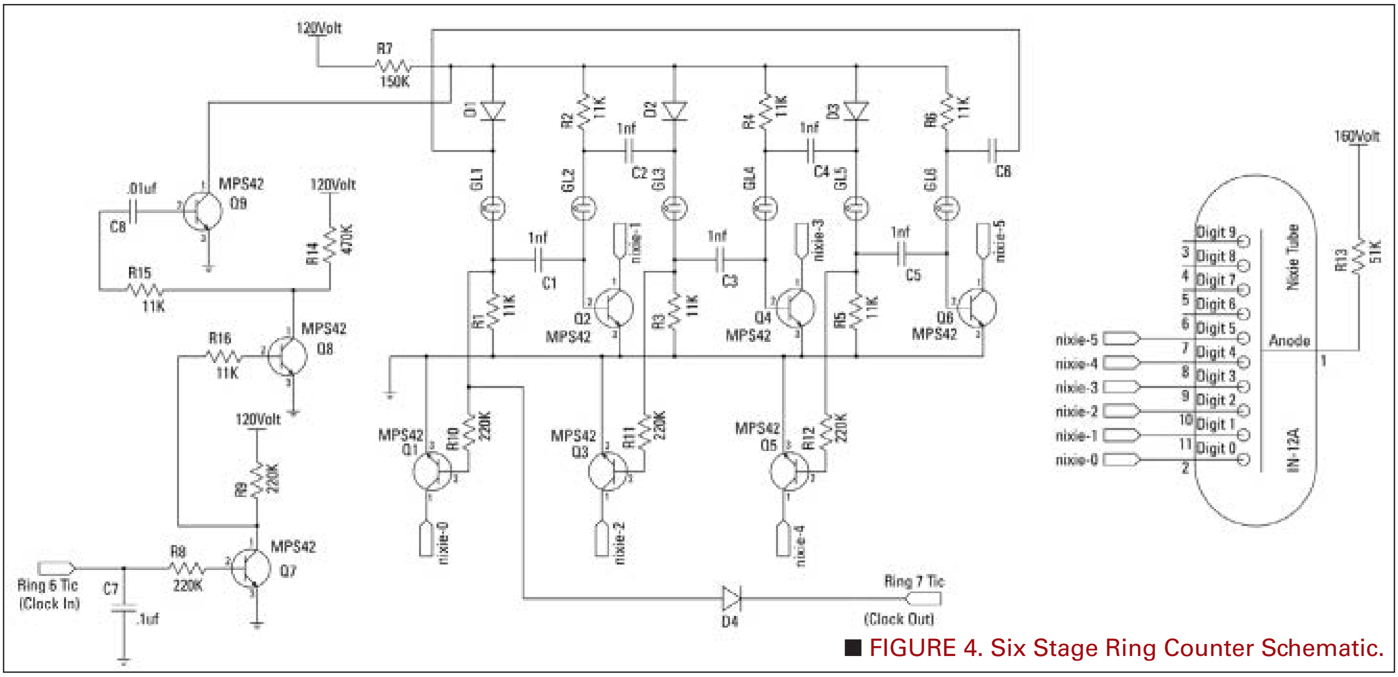
The clock consists of a high voltage power supply, seven ring counters, and an Atmel AVR processor. The power supply is shown in the schematic in **Figure 2**. It takes 12 volts AC and converts it to DC which drives the Maxim 1771 switching power supply to generate 160 volts. The Maxim 1771 operates by effectively shorting the 12 volts DC to ground through the coil L1 using the MOSFET Q1. When it turns off Q1, this releases the coil from ground and a large positive spike is generated which is then stored in an electrolytic capacitor C3. The diode D1 keeps the capacitor from discharging back though the circuit. Resistors R2, R4, and the potentiometer R3 make a voltage divider which feeds a small voltage back to the Maxim IC so that it can adjust the pulse's frequency and duty cycle to regulate the voltage. Resistor R5 and zener diode Z1 are used to regulate this down to 120 volts to drive the ring counters. The AC input is also used to provide a 60 Hz signal to the first ring, as well as an interrupt to the processor.

Three of the ring counters divide by 6, three others divide by 10, and the last ring divides by 12. The divide by 6 rings and the divide by 10 rings are paired to count the 60 Hz down to 1 Hz, the 1 Hz to 1 cpm, and the 1 cpm to an hourly pulse. Each of the rings are similar. The difference being the trigger circuit is different for the first two rings than the subsequent rings.

The first two rings use a single transistor to drive them, while a three-transistor circuit is used to provide clean, consistent pulses to drive the remaining rings. In addition to the different triggering circuits, the minutes and 10s of minutes rings have half of the diodes replaced with the



■ FIGURE 3. Ten Stage Ring Counter Schematic.



■ FIGURE 4. Six Stage Ring Counter Schematic.

base emitter junction of a transistor. Those transistors, as well as others, are used to drive the digits of the nixie tubes.

The schematic in **Figure 3** is indicative of the divide by 10 rings. It depicts the simpler 1-transistor trigger circuit which is used in the first two rings which divide the 60 Hz down to 1 Hz. Notice that the transistor is capacitively coupled to the ring, driving the positive side towards ground in short pulses.

The schematic in **Figure 4** is indicative of the divide by 6 rings. It depicts the more complex three-transistor trigger circuit used in the latter five rings. This trigger circuit uses the first two transistors to clean up the pulses from the previous stage which then are capacitively coupled to the third stage which is then tied directly to the ring. This provides a short, clean pulse to ground with each input transition from low to high.

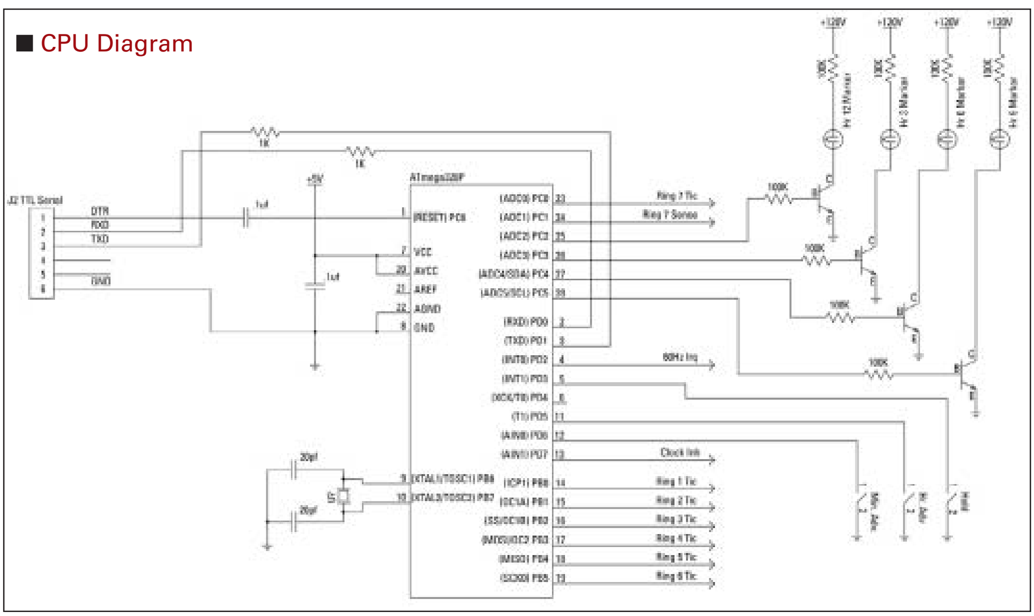
Figure 4 also depicts the nixie tube drivers. For driving the nixie tubes, three of the diodes tied to ground in the standard ring are replaced with the base-emitter junction of a transistor. When the neon lamp lights, the transistor turns on which lights the appropriate digit. This works for half of the digits. To drive the other half of the digits, a transistor is tied to the lamp side of the resistor through a resistor. The transistor drivers are only used in the ring for the minutes and the ring for the 10s of minutes.

To indicate hours, a 12 stage ring (which is not shown) is used. This ring is similar to the divide by 10 stage adding two stages to the ring, as well as using the three-transistor trigger circuit.

Ring Counter Operation

The ring counters work by relying on the fact that the neon lamps require a higher voltage to turn on than to remain lit. **Figure 3** will be used to explain the operation of the ring. On initially powering up the ring, one (maybe

■ CPU Diagram



more) lamp will light. We will assume that lamp GL3 is lit. This will put a 5 to 10 volt drop across R3 which will charge C3 to the same voltage through D4. If a positive pulse is applied to "Pulse In," a negative pulse will be applied to the ring counter which should extinguish the GL3. This will bring the voltage level on the resistor side of C3 to 0 which will force the diode side of the C3 to -5 to -10 volts. As the voltage is re-established on the ring, lamp GL4 will light up first because it will have the additional voltage of the capacitor as an advantage over the others. Once it lights, it will draw enough current through the 150K resistor R11 to lower the voltage on the ring down below the level that any of the other lamps will be able to light. The lighting of lamp GL4 will then charge C4 and the process will continue with each pulsing of "PulseIn."

To cascade rings, "Pulse Out" can be taken from the lamp side of any of the 11K resistors which are tied to ground. It must not be loaded too heavily by the successive stage or its operation will be effected. One important thing to remember — as far as the overall clock is considered — the stage which is used for "Pulse Out" will be 0 for that ring. This is most important for the minutes and 10s of minutes rings.

Board Construction

First, a warning! This clock uses 120 volts and 160 volts which are present throughout the board. Handle the board carefully! The corners are "ground" and the board can be held by them safely.

This board contains parts which must be installed in a certain direction.The electrolytic capacitors must have the positive lead (typically, the long lead) inserted into the hole with the square pad. There is a small plus sign by that pad, as well. Diodes must have their cathode inserted in the square hole. The cathode side of the diode has a stripe painted on it. The transistors and the regulator have their outline silkscreened on the board. Be sure to orient them correctly. The markings on the bridge rectifier are faint, but they match the markings on the silkscreen of the board. Pin 1 of the two integrated circuits has a square pad. Putting in any of the parts backwards will cause the clock to malfunction or damage to occur to the component or the clock.

I do not recommend using water soluble rosin core solder, either. My attempt at building one of these clocks with it just left me totally frustrated. The water soluble rosin is conductive and you need to wash the board, then dry it completely to test the clock as you build it. Any changes to parts of the rings involve a wash and dry cycle, as well.

If using the available printed circut board (PCB), the first step should be to solder in the pins for the nixie tubes. These are small and will not stay put until they are soldered. Insert each of the pins through their hole and then place a piece of cardboard over them and turn the

■ FIGURE 6. Completed Circuit Board.

board upside down and solder them in on the solder side. Once they have cooled, the board can be moved freely.

Next, the power supplies should be built; first, the low voltage portion, making sure that 12 volts (may be as high as 15 or 16 volts) and five volts are made. Then, build the high voltage portion. Make sure that it generates about 160 volts. Adjust R3 until it does. About 120 volts should be present on the cathode of Z1.

Next, the miscellaneous parts which have small quantities should be installed. These include the 51K, 100K, 1M, 470K, and 220K resistors. Follow these with the 20 pf, .01 µF, .1 µF, and the 150 µF capacitors. Once these are installed, install the MPSA42 transistors and the four colored neon bulbs which are a frosted white color when unlit.

Next, install the three micro switches, the socket for the CPU, 16 MHz crystal, two 1K resistors, and the J2 header. DO NOT INSTALL THE PROCESSOR YET.

Now we start work on building the ring counters themselves. One at a time starting with the bottom center ring counter, work your way around the board clockwise. We need to test each ring before moving to the next.

In an ideal world, the neon bulbs would have identical firing voltages. Sadly, they do not. After building a number of these clocks, I have found that most of them will only have one or two bulbs which don't want to work right. Other clocks have had five or six lamps misbehave.

Typically, the first two rings work when built. For the rings after the first two, I recommend they be breadboarded first using a protoboard to weed out any lamps which don't fire reliably (to be referenced as finicky from now on) or lamps which fire at a lower trigger voltage (to be referenced as erratic). Either of these types

of lamps will cause the ring to misstep.

Figure 2, can be used with the protoboard. When doing the six stage ring counter, simply don't populate the last four neon bulbs, and move the wire which feeds back the pulses from the last stage to the first over to stage 6.

Just above the second ring (near the switches), there are three test points: 120V, GND, and 1 Sec. Solder a wire to each of these to drive the protoboard.

Typically if there is a finicky lamp, one or more lamps will be skipped when the finicky one is supposed to light. This can be fixed by replacing the lamp which is the first not to light in the series. Erratic lamps will behave similarly except that at any point in the ring, the lamp will light and the count will pick up from there. Sadly, it is hard to distinguish the two though I found more often than not that I should assume a finicky lamp before an erratic lamp.

Start assembling a ring by soldering in the diodes. Be sure to take note that the wire of the cathode side of the diode (the side with the line) should be inserted into the hole with the square pad. Follow the diodes with the 11K resistors. Follow these with the capacitors. The capacitor symbol is a bit hard to see; it is two lines which are broken as they pass between the two pads for the capacitor. Install the transistors for the rings next. The fifth and sixth rings, will require more transistors than the other rings.

Once the transistors are in, solder in the neon lamps. On many of my clocks, I have placed a small glass bead on each lead of the lamps to act as a standoff. Be sure to solder them in straight, otherwise the rings won't look right. After I solder in the lamps and check that the ring is operating properly, I straighten any bulbs by melting the solder of one leg and tilting it upright.

To test a stage, turn on the clock and verify that one or more lamps light up. It should be easy to determine if the first three rings are operating. After this, the sequencing is slow enough to make it harder to tell. To speed this up, connect a wire between the 1 sec test point to the test point feeding the ring in question. This should cycle the ring at 1 Hz.

For the minutes and 10s of minutes stages, you can install the appropriate nixie tube for the stage and verify that all of the digits work as you expect. In both of the rings, the neon bulbs have the number of the digit they

PARTS LIST

❑ 1	IC Socket 28-Pin	(Mouser #: 571-1-390261-9; **www.mouser.com**)
❑ 1	HC-49/S Crystal - 16 MHz 20 pF	(Mouser #: 73-XT49S1600-20)
❑ 3	Fuses - Axial Lead, 125V .5A	(Mouser #: 576-0251.500MXL)
❑ 2	1/8W 5% Carbon Film Resistors - 1.0K ohms	(Mouser #: 299-1K-RC)
❑ 1	1/8W 5% Carbon Film Resistors - 1.2K ohms	(Mouser #: 299-1.2K-RC)
❑ 1	1/8W 5% Carbon Film Resistors - 2.2K ohms	(Mouser #: 299-2.2K-RC)
❑ 4	1/8W 5% Carbon Film Resistors - 51K ohms	(Mouser #: 299-51K-RC)10
❑ 10	1/8W 5% Carbon Film Resistors - 100K ohms	(Mouser #: 299-100K-RC)
❑ 6	1/8W 5% Carbon Film Resistors - 1M ohms	(Mouser #: 299-1M-RC)
❑ 5	1/8W 5% Carbon Film Resistors - 470K ohms	(Mouser #: 299-470K-RC)
❑ 7	1/8W 5% Carbon Film Resistors - 150K ohms	(Mouser #: 299-150K-RC)
❑ 22	1/8W 5% Carbon Film Resistors - 220K ohms	(Mouser #: 299-220K-RC)
❑ 80	1/8W 1% Metal Film Resistors - 11K ohms 50 PPM	(Mouser #: 270-11K-RC)
❑ 1	1/2W 5% Resistor - .1 ohms	(Mouser #: 660-SPRX1/2CT52RR10J)
❑ 1	Multi-Turn Potentiometer - 20K ohms	(Mouser #: 81-PV36W203C01B00)
❑ 2	Ceramic Disc Capacitors - 20 pF 50V	(Mouser #: 140-50N2-200J-RC)
❑ 11	Capacitors - 0.1 µF 50 volts	(Mouser #: 81-RPEE41H104M2K1A03)
❑ 1	Capacitors - 2200 pF 200 volts	(Mouser #: 80-C320C222J)
❑ 61	Capacitors - 1,000 pF 50 volts	(Mouser #: 81-RPER71102K2P1A03B)
❑ 5	Capacitors - 0.01 µF 50 volts	(Mouser #: 81-RPEE41103M2K1A03B)
❑ 1	Electrolytic Capacitors - 10 µF 250 volts	(Mouser #: 75-515D106M250CG6A)
❑ 7	Electrolytic Capacitors - 10 µF 160V	(Mouser #: 140-XRL160V10-RC)
❑ 2	Low ESR Electrolytic Capacitors - 100 µF 25 volts	(Mouser #: 140-ESRL25V100-RC)
❑ 1	Inductors Radial Lead - 220 UH	(Mouser # 580-18R224C)
❑ 70	Neon Base Wire Terminal - 65 VAC .7 mA NE-2E	(Mouser #: 606-A9A)
❑ 1	Rectifiers - Bridge 1A 50V	(Mouser #: 583-DB101)
❑ 3	Snap-Action Switches - 50 MA Insert Left	(Mouser #: 540-DG23-B3LA)
❑ 1	DC Power Jacks PCB 2.1 MM	(Mouser #: 163-179PH-EX)
❑ 1	Fast Recovery Rectifiers - 1.0A 400V	(Mouser #: 625-1N4936-E3)
❑ 67	Diodes 1SS244 - 200 MA 250V	(Mouser #: 755-1SS244T-77)
❑ 1	Zener 1N5380 - 120V 5W	(Mouser #: 863-1N5380BG)
❑ 1	IRF830 MOSFET Transistors N-Chan 500V 5.0A	(Mouser #: 844-IRF830APBF)
❑ 1	LM78L05 Linear Regulators 0.1A Pos Volt Reg	(Mouser #: 512-LM78L05ACZ)
❑ 38	MPSA42 Transistors NPN High Voltage Transistor	(Mouser #: 512-MPSA42_J18Z)
❑ 24	Socket Receptacles	(Mouser #: 575-032700)
❑ 4	Spacers and Standoffs HEX .250x.500 Alum	(Mouser #: 534-2210)
❑ 4	Spacers and Standoffs AL 1.500 M/F Thrd	(Mouser #: 534-8422)
❑ 1	AC Adaptors - 12 VAC 500 MA 2.1 MM	(Mouser #: 412-212054)
❑ 2	IN-12a Nixie Tubes	(**www.AllSpectrum.com** # IN-12A)
❑ 4	Green or Blue 15 mm Neon Bulbs	(**www.AllSpectrum.com** # NE-2B-6x15x30)
❑ 1	Maxim 1771 Power Supply IC	(**www.AllSpectrum.com** # MAX1771)
❑ 1	ATmega 328P Processor with Arduino Bootloader	(**www.sparkfun.com** # DEV-09217)
Optional but recommended:		
❑ 1	Solderless Breadboards 630 + 200 Tie Points	(Mouser # 589-TW-E40-1020)
❑ 1	USB to 5V serial converter	(**www.sparkfun.com** # DEV-09115)

are associated with printed on the silkscreen. Unplug the adapter and move to the next stage until all of the stages are complete.

Clock Operation

On power-up, the clock will reset itself to 01:00:00. Reading the clock is fairly straightforward. The minutes are displayed on the two digits while the hours are displayed by the circle of 12 neon bulbs encircling the digits.

The time can be set by pressing the Min. Adv. or Hour Adv. buttons. When either of these buttons are first pressed, the clock will sequence to the time it has saved in its memory. Once it has set the time, pressing and holding either the Min. Adv. or Hour Adv. button will advance the minutes or the hours, respectively. You can go back and forth between the two switches setting the minutes and hours as needed. The clock will hold its time until the Pause button is pressed and released.

The rings can be run at an accelerated rate. This is useful for forcing rings to miscount. By pressing the Hold button and the Hour Adv. button simultaneously, the processor will take over and run the first ring. It will only be at a slightly different speed than normal. Pressing the Min. Adv. button will cause the processor to move to the next ring. Subsequent presses of the Min. Adv. button will cause the processor to sequence each ring. Pressing and releasing the Hold button will cause the clock to set itself to the current time, then resume normal operation.

A note of caution! When you go to touch the clock, you should try to discharge yourself first. I haven't damaged a clock with a static zap, but I have made them display some interesting times on their rings.

Software

The source code and upgrades, as well as instructions for building and downloading it to the clock, can be found at **www.nixieneon.com**, or **www.nutsvolts.com** The software for the board is released under the GNU GPL license. It can be downloaded using the program avrdude from **www.arduino.com** or by using WinAvr which can be found at **http://sourceforge.net/projects/winavr/**. WinAvr is a complete development system. The clock can be communicated with using the TTL level serial port on J2. The pinout for this header matches the FTDI USB-to-serial converter board sold at **www.sparkfun.com**. Be sure to get the five volt version. The following commands are available through the serial port. Each command should be typed in, followed by the enter key. Any subsequent input needed will be prompted for.

razzle	Makes the rings dance.
reset	Resets the time to 01:00:00.
seqtime	Sets the speed to run the rings in the diagnostic mode.
settime	Sets the time.
step	Steps individual rings for diagnostics.
sync	Runs the rings to set the clock to its current time.
synctime	Sets the time interval in seconds; the clock will reset its time.

Wrap Up

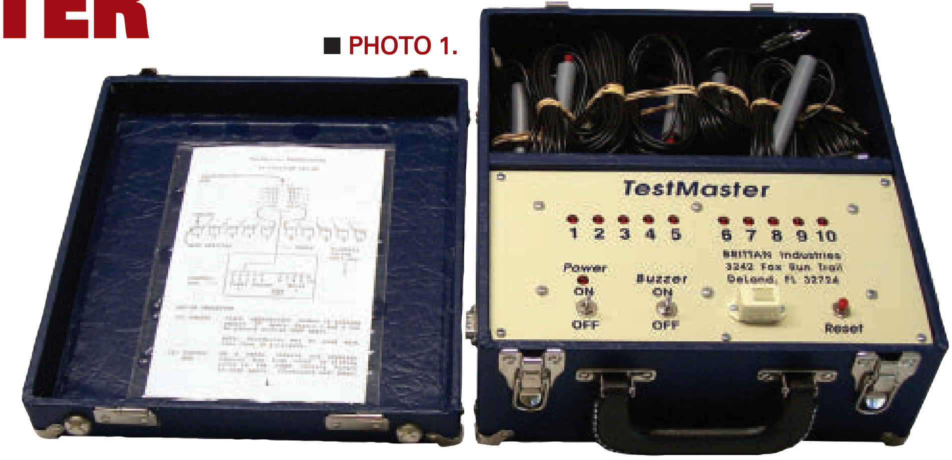
I believe that I have come up with an intriguing clock design which can provide hours of enjoyment and satisfaction both in its construction, as well as watching it work once it is complete. With over 400 parts, it should prove to be a good challenge for anyone, with the reward of having a very unique nixie clocks. As a benefit, if the builder doesn't have much time soldering under their belt, they will by the time this clock is complete! **NV**

A complete kit for this project can be purchased online from the *Nuts & Volts* Webstore or call our order desk.
www.nutsvolts.com
800 783-4624

TESTMASTER QUIZ BOX

by John L. Brittan

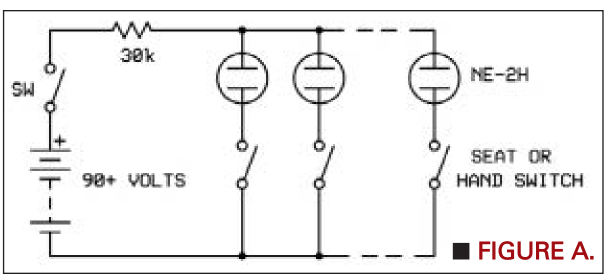
■ PHOTO 1.



In the mid-1950s, I was asked to be one of three judges to participate in a Bible Quiz. The judges stood in the back of a high school auditorium. The quizzers were on stage sitting on chairs. The judges had to hold a 4x5 inch card in front of their eyes in such a way that the top edge would be above the heads of the quizzers. When a question was asked by the quiz Master, the contestants that knew the answer would jump up. Two out of three judges were to decide who jumped first. You guessed it. It was an impossible task.

After that evening, I decided to work out an electronic method to determine who jumped first using NE-2H neon lamp characteristics. I knew that the neon lamp needed to see 90+ volts to fire. After firing, the voltage would drop to 55 volts. I concluded that putting lamps in a parallel switch configuration should work as the first lamp switched ON would not allow the others to fire since the 90+ volts would be only 55 volts. Take a look at **Figure A**. The 30K ohm series resistor is needed to limit the lamp current to about two milliamperes.

Problems with this circuit came about when quizzers jiggled around on their seat switch or if the first quizzer to jump decided to sit back down. Their switch would still open, their lamp would go out, the voltage would go back to 90+ volts, and fire another lamp.



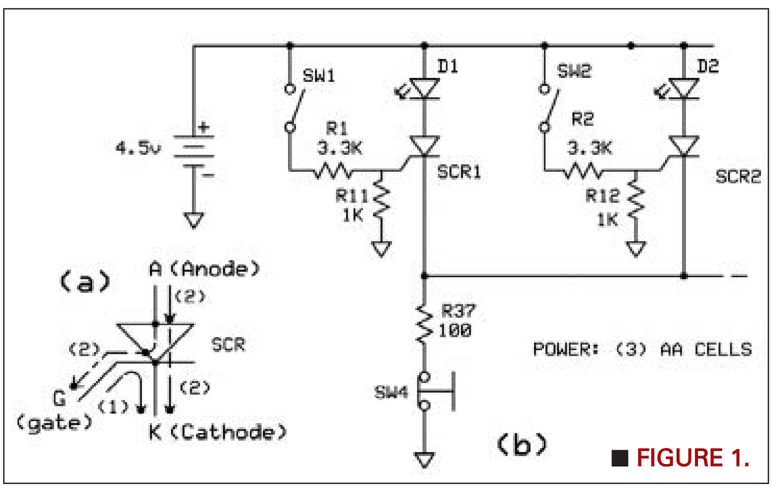
■ FIGURE A.

I have been involved with quizzing for over 50 years. Of all of the quiz boxes I have constructed, the quiz box presented here is my best design. The TestMaster Quiz Box is portable using only three AA cells (4.5 volts). It has no moving parts (relays) except the hand switches, and no digital circuitry with the exception of the 10 second 555 timer and several other timing circuits. There is a 10-hand switch storage compartment, a provision for two or more quiz boxes to be connected together (no limit), and 10 LED lights and a buzzer signal for when a hand switch has been depressed (see **Photo 1**).

This hardware project uses an analog biasing method to lock out all but the first response in such a way that it is impossible for a tie to occur (see Circuit Theory). Seat switches are complicated to make, so I chose to make a simple hand switch using a pushbutton switch and 3″ x 1/2″ O.D. PEX water pipe.

Circuit Theory

The silicon controlled rectifier (SCR) is used as the primary device to latch the circuit ON, causing lockout of the rest of the hand switches. **Figure 1-a** shows the schematic of the SCR transistor. Instead of using base, emitter, and



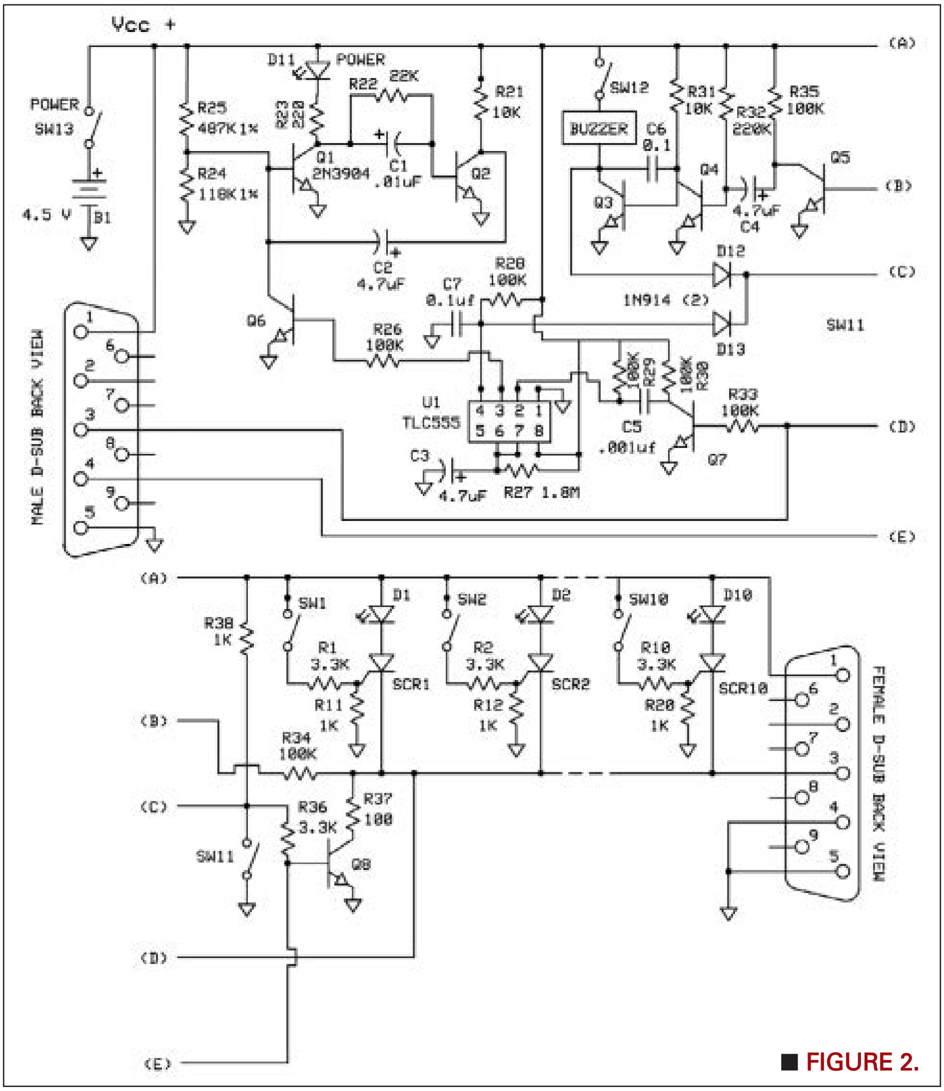
■ FIGURE 1.

collector to define the electrodes, gate is used for base, anode for collector, and cathode (K) for emitter. When a hand switch is closed, positive charge flows into the gate-cathode material as indicated by the number (1) current arrow. Gate-cathode current (1) causes the SCR to turn ON as indicated by anode-cathode current (2). If a return path such as a 1K resistor is provided between gate and ground, the gate current will reverse direction and is indicated as positive charge (2). Once the SCR turns ON, the gate has no control over the anode-cathode path. Causing the anode-cathode current to go to zero will reset the SCR to the OFF state. The RESET switch — located to the right of the buzzer — performs this operation (see **Photo 2**).

Figure 1-b is a simplified schematic of the hand switch concept. As long as hand switch SW1 and SW2 are open, neither LED D1 nor D2 will light up. If we close hand switch 2, positive charge will flow through the 3.3K and 1K ohm voltage divider causing one volt to appear at the gate of SCR2. The one volt now causes positive charge [current (1)] to flow into the gate-cathode circuit thus turning ON SCR2's anode-cathode current [current (2)]. The SCR2 anode-cathode current continues down through the 100 ohm resistor R37 causing 1.7 volts to appear across it. Note that the cathodes of SCR1 and SCR2 are connected together and that the 1.7 volts now exist at the cathode of SCR1. Closing hand switch SW1 causes one volt to appear at the gate of SCR1. However, 1.7 volts at the cathode of SCR1 and only one volt at its gate says that SCR1 sees -0.7 volts and it will never turn ON — thus the lockout feature. To now turn ON SCR1, the gate voltage of 2.7 volts would be needed and the 3.3K and 1K ohm voltage divider will not let this happen. Switch SW4 is used to reset the circuit by causing the anode-cathode current to go to zero.

It is interesting to note that after hand switch SW2 is depressed, the voltage at the SCR2 gate jumps to 2.3 volts. Remember, the voltage divider creates one volt for the gate when SW2 is closed. The gate current reverses direction after SCR2 turns ON and this causes the 2.3 volts to appear across the 1K resistor. Also, the reset switch SW4 used in the final circuit is a normally open switch (not normally closed). This is the same switch used for the hand switches. How I got a NO switch to act as an NC switch will be covered when we look at the circuit schematic.

■ PHOTO 2.



■ FIGURE 2.

The Complete Schematic Diagram

Figure 2 shows the complete schematic of the quiz box electronics. As you study the diagram, you recognize the SCR-LED-hand switch circuitry. Only three of the 10 SCRs are shown for clarity. As mentioned before, all 10 SCR cathodes are tied together and connected to R37, a 100 ohm resistor. To reset the ON SCR to OFF, disconnect the 100 ohm resistor. Transistor Q8, 3.3K (R36), 1K (R38), and the SW11 NO push button switch perform this task. Q8 is biased ON by R38 and R36, thus shorting one lead of the 100 ohm R37 to ground. Depressing switch SW11 removes the base bias on Q8 causing Q8 to turn OFF. This, in effect, disconnects R37 from ground causing the SCR circuit to reset.

At the time the RESET switch is depressed, the BUZZER sounds, announcing the start of the next question. Follow line "C" from RESET switch SW11 to the top of the schematic of the past diode D12 and up to the BUZZER. If toggle switch SW12 is closed, the BUZZER will sound. Also, when a contestant depresses his or her hand switch, the buzzer sounds for one second to let the Quiz Master know a hand switch has been depressed. This is accomplished by the BUZZER circuit Q3, Q4, and Q5.

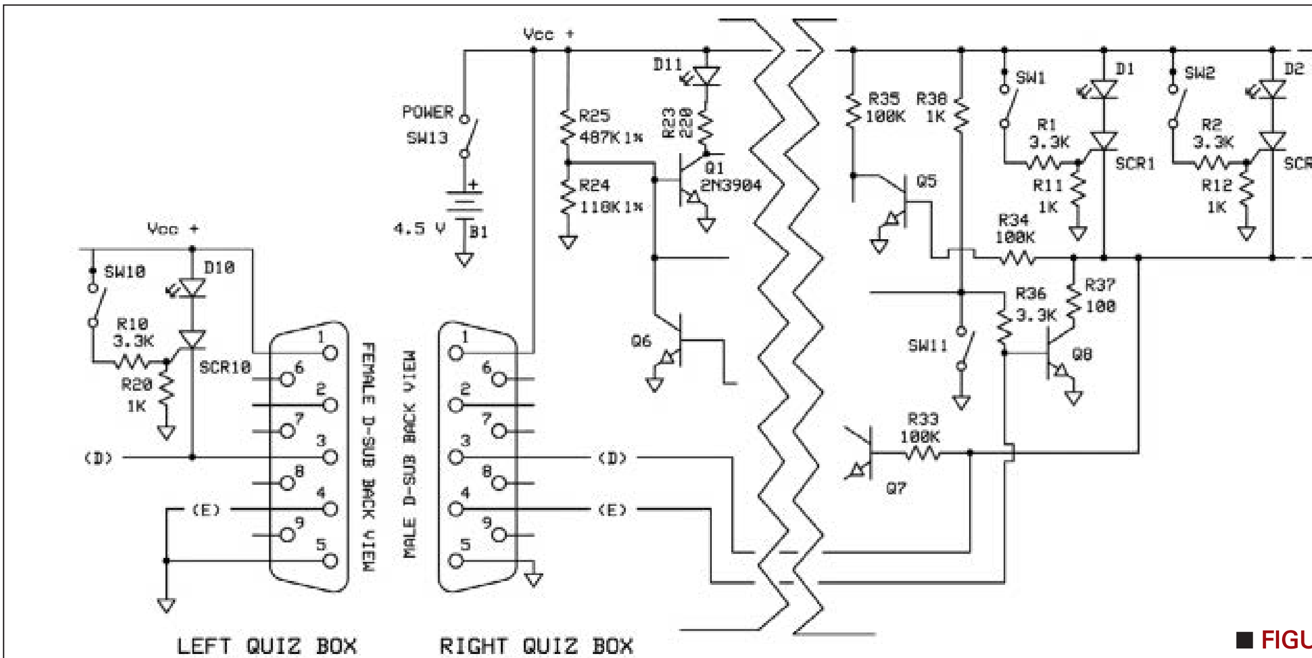
The monostable (one shot) one second timer gets its command to turn ON the BUZZER from the base of Q5, circuit (B), through the 100K ohm (R34) resistor connected to the SCR cathode bias voltage (1.7V) signal at the moment a hand switch is depressed. To turn ON the BUZZER, the Q3 collector to emitter path must be ON. Diode D12 (circuit "C") is blocking the Q8 base bias from going to zero via Q3's ON condition. Without diode D12, the SCRs would reset immediately after a hand switch is depressed.

The Power LED Indicator

To conserve power, transistors Q1 and Q2 pulse the LED D11 power ON indicator about every second. The 1% resistors R24 and R25 voltage divider bias the base of Q1. However, when battery voltage falls to about 3.2 volts, the voltage divider voltage to the base of Q1 will be below 0.6 volts. This will shut off Q1 and its associated LED D11 indicating the batteries need to be replaced. (The batteries will last a long time if you remember to turn the Quiz Box OFF after each quizzing session.) The idling battery current is about 7 mA, and when a hand switch is depressed the current jumps to about 22 mA.

The 555 10 Second Timer

The contestants are given 10 seconds (you can change R27 to suit your rules) to answer the question after they depress their hand switches. Line "D" samples the 1.7 volt signal from the SCR's cathode circuit through a 100K ohm (R33) resistor to the base of Q7. This turns Q7 ON causing a negative going pulse to trigger pin 2 of the 555 chip. The output — pin 3 — goes high, turning Q6 ON which shorts the base of Q1, thus stopping the pulsing power circuit and LED D11. After 10 seconds, pin 3 goes low, Q6 goes OFF, and the power light starts blinking telling the Quiz Master the 10 seconds have expired. Pin 4 of the 555 is the reset function. R28 and C7 reset the timer at power ON so the power LED D11 will start functioning immediately. Otherwise, the 555 can false trigger and go into its 10 second time-out when the power switch is turned ON. You would then go into cardiac arrest thinking that the power was dead. Diode D13 blocks line "C" Q8 base bias voltage from interfering with pin 4 start-up action.



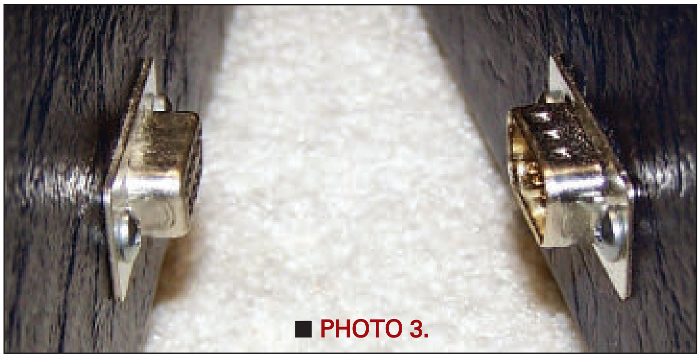
■ FIGURE 3.

Connecting 2 or More Quiz Boxes

Figure 3 shows the schematic for when two or more quiz boxes are connected together (also see Photo 3). Observe that pin 1 of both D-SUB sockets connects Vcc + of both quiz boxes and pin 5 connects the grounds. What happens to the base of Q8, the reset circuit? Pin 4 of line "E" says that the base of Q8 gets grounded. The reset switch on all quiz boxes connected on the right side of the first quiz box no longer function. The left quiz box becomes the control box.

Now look at line "D", pin 3, and realize that all of the SCR cathodes of both boxes are connected. The two quiz boxes now function as one 20 contestant quiz box. There is no limit to the number of boxes that can be connected together. Any four-pin male and female round plug and socket can be mounted on the side of the wood case to use however, the D-SUB socket has not been easy to install.

Note: When connecting two or more quiz boxes, have all power switched OFF on all boxes until the boxes are properly connected. Turn OFF all BUZZER switches except the leftmost box to conserve power and extra noise. When all boxes are connected and you are ready to quiz, turn ON all the power switches on all the boxes.



■ PHOTO 3.

Circuit Board Construction

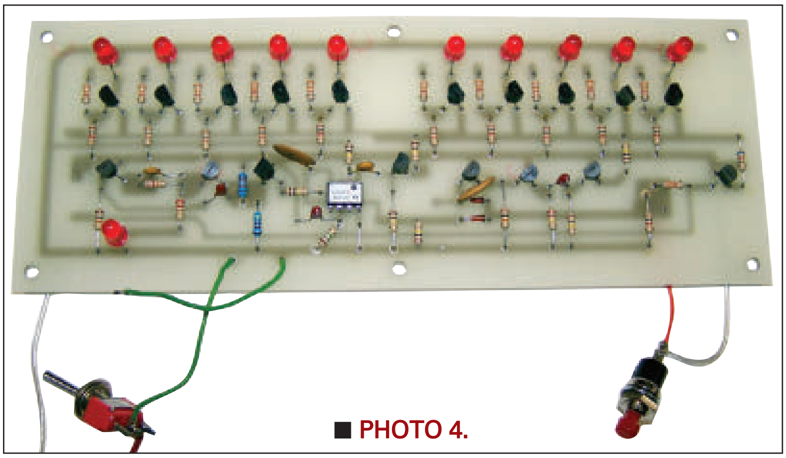
Figure 4 and **Photo 4** show the layout and placement of parts on the PCB (printed circuit board). A suggested PCB construction goes as follows:

1. Insert and solder resistors R1-R10, 3.3K ohm, at the top of board. The last 3.3K ohm resistor is R36 located at the lower righthand corner.

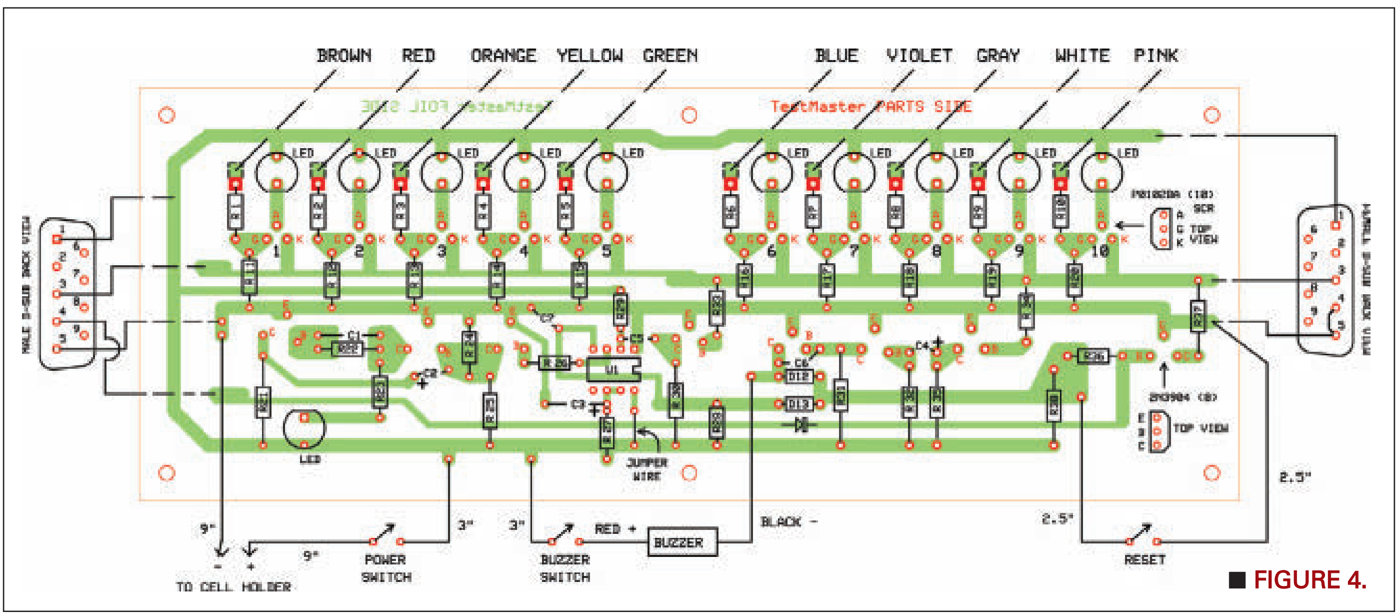
2. Place resistors R11-R20 and R-38, 1K ohm. Using the Parts List, put the remainder of the resistors and two diodes on the board. The cathode of both diodes (D12, D13) is to the right as the symbol indicates.

3. The SCRs should now be installed. The pin-out is shown in the upper righthand corner of **Figure 4**. A top view of the SCR is shown defining the (A) anode, (G) gate, and (K) cathode.

4. The 2N3904 transistors are next with the pin-out shown at the lower righthand corner of **Figure 4**. There

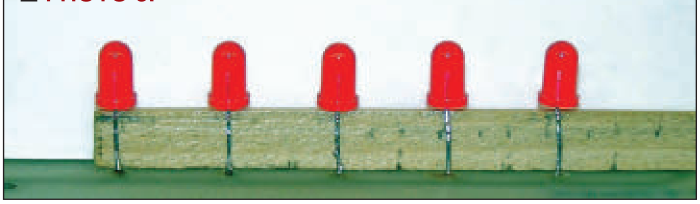


■ PHOTO 4.



■ FIGURE 4.

■ PHOTO 5.



are eight of these transistors. A transistor goes where you see a cluster of B, E, and C letters.

5. The 555 (U1) is mounted next. Make sure pin 1 is opposite C5.

6. Now mount the capacitors starting with C1, a 0.01 µF ceramic disc. C1 is located at the far left near the middle of the board. C2, C3, and C4 are 4.7 µf tantalum polarized capacitors. Look for the + sign on **Figure 4** at C2, C3, and C4. C5 is a 0.001 µF ceramic located next to the 555 chip, U1. C6 (a 0.1 µF ceramic) is located above the two diodes. C7 (also 0.1 µF) is located near U1 above R26.

7. The 10 LEDs are mounted using a spacer. Look at **Photo 5**. The wood spacer is seven inches long, 0.35 inches high, 0.1 inches thick at the base, and tapered to 0.05 thickness at the top. It's shaped like a trapezoid. Be sure that the flat side of the base of the LED is positioned as shown in Figure 4. Put the wood spacer in place and solder only one lead of each LED. This will allow you to pull out the wood spacer. Sight down the LED row and adjust any that are out of line. Now solder the other lead. The POWER LED is located at the lower left corner next to R21. The flat side is facing in towards the center of the board. Use the wood spacer and solder only one lead. Remove the spacer and solder the second lead.

8. Install the jumper wire next to the 555 chip as shown on **Figure 4**.

9. Figure 5 is an x-ray view of the foil as seen from the parts side. My CAD software (free from ExpressPCB) will not allow me to flip the board over. Start at the bottom left side of the board and note a nine inch (preferably a #20 stranded black) wire connected underneath it going to the cell holder negative terminal. Do not solder to the cell holder at this time. Using a different color wire, (red, for example), connect a nine inch #20 stranded wire to a toggle switch. Now connect a three inch wire from the switch to the board as shown. This becomes the POWER switch. Twist the two nine inch wires together for about five inches starting at the cell holder end.

10. The BUZZER switch is next. Solder a three inch wire to the board and switch. The BUZZER has its own red and black wire, and will be addressed when it is fastened to the front panel.

11. The RESET switch (far right) is a push button switch, the same used at the hand switches. Connect two 2.5 inch wires to the switch and to the board as indicated in **Figure 5** — the left wire on the top of the board and the right wire underneath the board. Just sweat the wire to the foil. Set the PCB board aside for now.

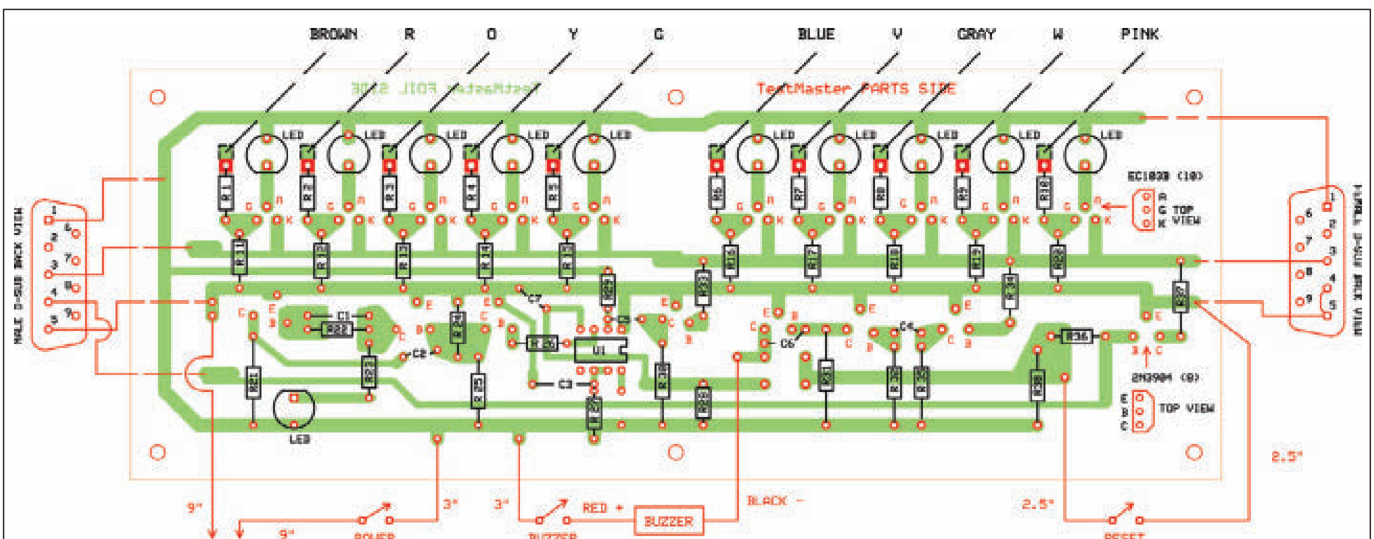
Front Panel Construction

Patterns for construction of the actual quiz box (listed as **Figures 6 and 7**) are available on the *Nuts & Volts* website at **www.nutsvolts.com** along with all the other necessary files to complete this project. The front panel board is 10 x 5.2 x 0.1 inches and is made of Masonite material. I spray paint the board and then silkscreen the letters/numbers on. Using a punch works better than drilling.

Construct the front panel as follows:

1. Mount the BUZZER to the front panel by pushing the two wires from the buzzer through the middle 7/64" hole. Use two #2-56 x 1/2" screws through the buzzer mounting holes and then down through the remaining 7/64" holes. Using #2 tooth washers and nuts, secure the buzzer to the front panel.

2. Solder the black BUZZER wire to the top of the PCB as shown in **Figure 5**. Solder the red buzzer wire



■ FIGURE 5.

to the buzzer switch.

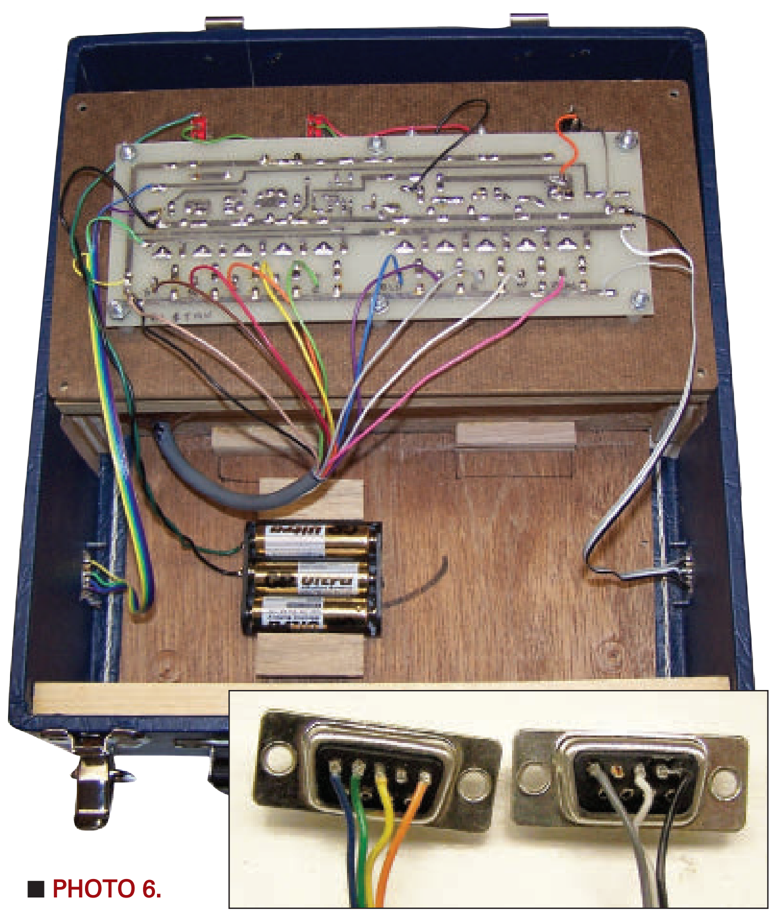
3. Using six #6-32 x 1″ screws, 1/2 inch nylon spacers, and #6 tooth washers and nuts, fasten the PCB to the front panel.

4. Fasten the toggle power switch, toggle buzzer switch, and push button reset switch to the front panel. Don't use the split washer that comes with the push button switch. Set the front panel and PCB aside.

Quiz Box Construction

The quiz box is constructed from 1/4 inch plywood. A 3/8 inch divider separates the hand switch storage compartment from the battery and electronics area. Note the four inch dimension for the height of the box. Since the box cover is about 1-3/4 inches in depth, I recommend that you build a box 10-1/2 x 11-1/4 x 5-3/4. Using your table saw set to four inches, cut the cover away from the rest of the box. You will then have a cover that is 10-1/2 x 11-1/4 x 1-3/4 minus the saw cut. This way, the cover should fit the box (mark which way the cover goes).

The divider is made of 10 x 3-3/4 x 3/8 inch plywood. A 5/16 inch diameter hole is drilled to make way for the 12-wire cable. There are two 1/2 x 1/2 x 10 inch pine boards glued to the box and divider 3/8 inches down from the top of the box that will hold the front panel in place. Remember to cut the opening for the D-SUB connectors on both the right and left sides of the box. The box and lid are covered with blue vinyl cloth. Look at **Photos 1** and **2** to see how the handle, hinges, and locking hardware are mounted on the lid and box. The hinges are the kind that separate so the cover can be removed.



■ PHOTO 6.

■ PHOTO 7.

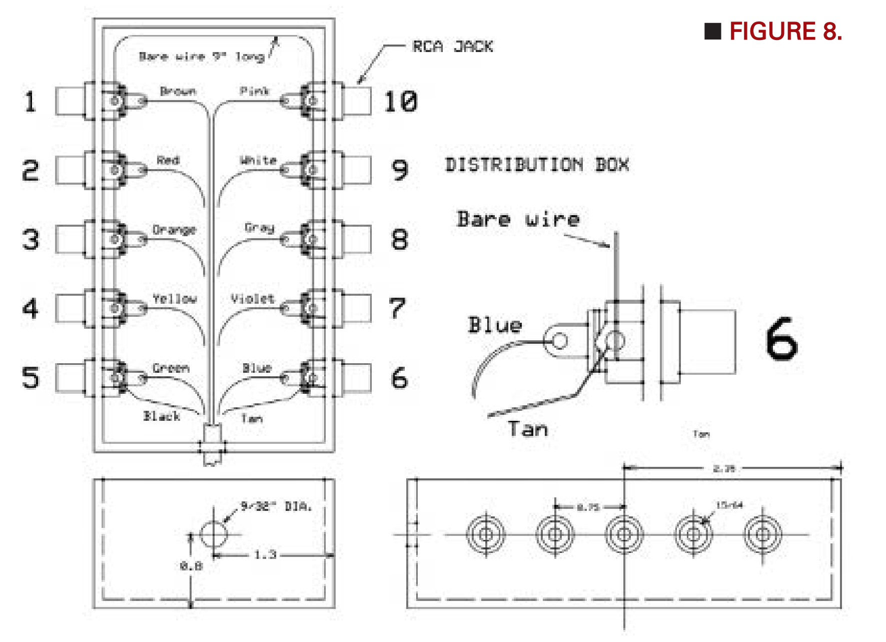
D-sub Connectors and Cables

The **Photo 6** inset shows that the male D-SUB connector has four colored wires attached to it. The female D-SUB connector has only three colored wires. I use 10 inches of 10-conductor ribbon cable, separating four conductors away from three conductors. Using **Figure 5** as a guide, solder wires to pins 1, 3, 4, and 5 of the male connector. Make a note of the color code and pin numbers. I put the lightest color on pin 1. Feed the four wires through the left hole on the box and secure the connector with two #4 x 3/4″ Phillips pan head sheet metal screws.

The female connector has to have pins 4 and 5 connected together with one wire. I use the darkest color here. Pins 3 and 1 are connected next. Note that pin 2 is not used in either connector. Again, make a note of the color code and pin numbers. Feed the three wires through the right hole on the box and secure the connector with two #4 screws. Set the quiz box aside. The D-SUB connector wires will be connected to the front panel later.

12-Conductor Wire and Distribution Box

Remove the distribution box cover and note the ribs used to hold PCBs. Remove these ribs using a wood chisel. Next, study **Photo 7** and the diagram in **Figure 8**. Drill a 9/32 inch hole at one end for the 12-conductor cable. Using a 15/64 inch drill, drill five holes on each side 3/4 inches apart to receive the RCA jacks. Thread the jacks through the hole for a snug fit. The jack comes with a solder lug that is to be positioned straight up. Twist the solder lug about 45 degrees so that a nine inch long bare wire can be passed through each lug. A #18 or #22 wire will do. Solder all connections except jacks 5 and 6.



■ FIGURE 8.

Solder all connections using **Figure 8**'s wire color code. This can be done quickly by putting some solder on the tip of the RCA jack center electrode and sweating each wire to the tip electrode. The black and tan wires go to solder lugs 5 and 6.

Glue the copper wire clamp to the inside of the box. This is done by placing a C clamp tight against the outside of the box and cable, and then pushing the 1/2 inch pigtail down to the bottom of the box so that it won't interfere with the cover. Glue all around the copper wire clamp with Amazing GOOP® glue. Prop the box up so that the glue at the copper wire clamp does not run out of the box. GOOP needs at least 12 hours to cure. Next, place 3/8" press-on numbers 1 to 10 as shown in **Photo 7**.

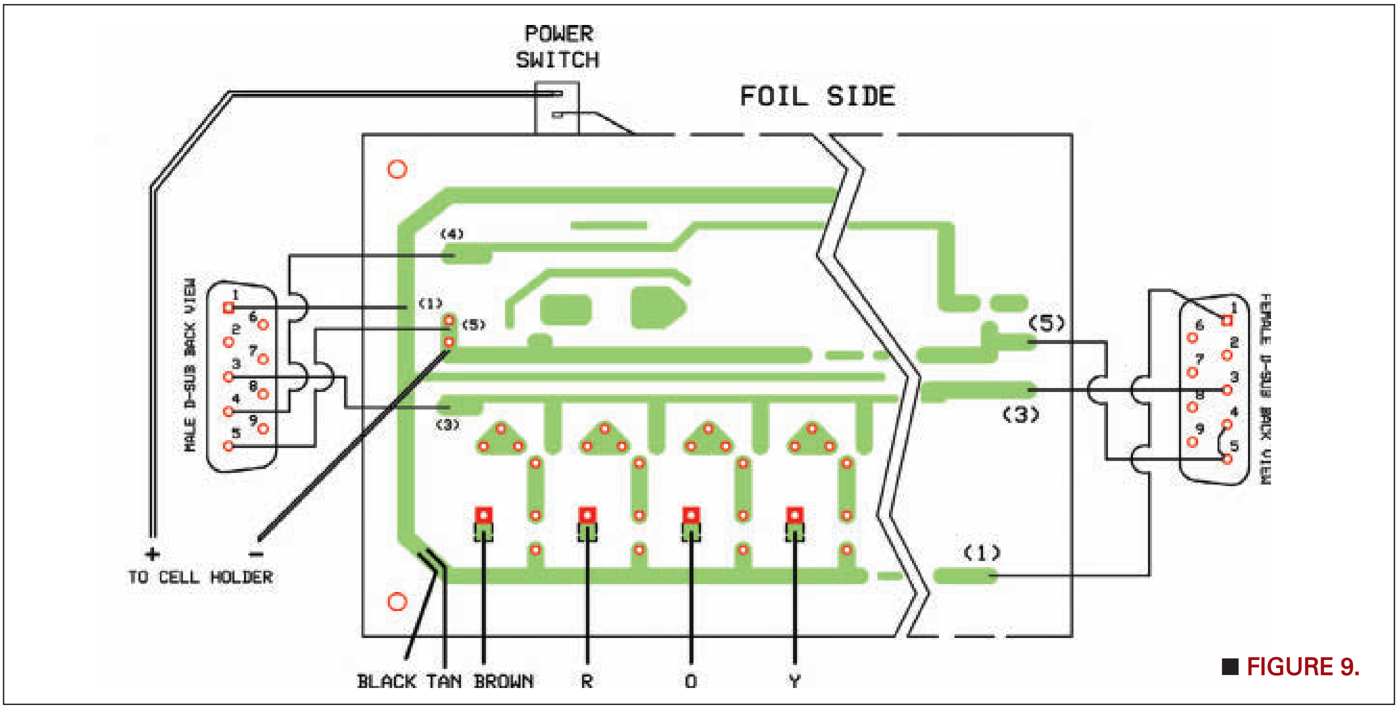
The 12-conductor wire is 16 feet, eight inches long with four inches of outer sleeving removed. If the cable is much longer than 16 ft, it may not fit in the storage compartment.

Remove 1/4 inch of insulation from each wire. Tin each wire. Now feed the cable through the 9/32 inch hole until the brown wire easily reaches jack 1. To keep the cable from twisting inside the box and coming out of the end hole during use, make a clamp (on the inside of the box) by wrapping three turns of #14 bare copper wire around the cable. Twist the ends so that the bare wire tightens around the cable. Clip the pigtail to about 1/2 inch.

Connecting the 12-Conductor Cable to the Quiz Box

From the storage compartment, pass the 12-conductor cable through the 9/32 inch hole in the divider of the quiz box (left bottom) as shown in **Photo 6**. Remove six inches of the outer sleeving. Remove 1/4 inch of insulation from each wire. Tin each wire in preparation for sweating it to the PCB front panel. Position the front panel and PCB as shown in **Photo 6**. The toggle and reset switches will be at the back of the quiz box near the hinges.

At **Figure 9**, look at the lowerleft hand corner. Locate the wire marked as brown. Sweat the end of the brown



■ FIGURE 9.

wire from the cable to the pad as indicated. Continue to solder the red, orange, yellow, green, blue, violet, gray, white, and pink cable wires to their respective foil pads. Twist the ends of the black and tan wires together. Solder them to the outer foil ast the left of the brown wire as shown in **Figure 9**.

As before, at the 9/32 inch hole make a clamp around the cable using three turns of #14 wire. Glue with GOOP so that the cable will be secure.

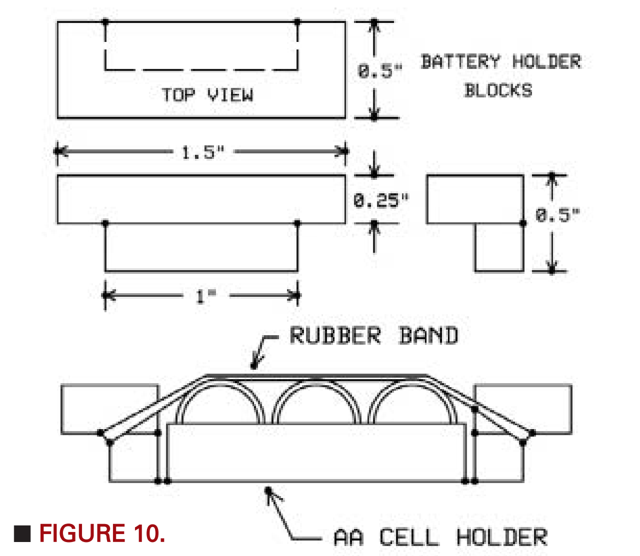
Connecting the D-Sub Connector and Power supply Wires

Connect the four male D-SUB wires (see **Figure 9**) by sweating the wires to the proper circuit board foil. The wire from D-SUB pin 4 goes to the foil marked 4, etc. Likewise, connect the female D-SUB wires to the proper circuit board foil (as also shown in **Figure 9**).

Photo 6 shows how to position the three-cell AA battery holder. The black negative wire is soldered to the middle connector opposite the spring and the red positive wire next to it. Use GOOP to glue the battery holder to the bottom of the box. The AA cells are held in place by a size 33 rubber band and two blocks of wood (**Photo 6**). A 1″ x 1/4″ x 1/4″ piece is glued to a 1.5″ x 1/2″ x 1/4″ piece of wood as shown in **Figure 10**. Glue the two wood pieces to the bottom of the box with the flat side next to the battery holder. Give the glue 12 hours to cure. After placing the cells into the battery holder, wrap a size 33 rubber band twice over the battery holder and blocks.

Testing Out the Quiz Box

Turn the front panel over and switch the power to ON. If the electrical circuit has been constructed correctly, the POWER LED will start blinking. Make sure the buzzer switch is ON. Depress the reset push button switch. The buzzer should sound.



■ FIGURE 10.

If nothing happens, turn the front panel over so you can check the voltage (4.5 volt) at the three-cell battery holder terminals. Next, check the voltage at the PCB by connecting the negative lead from your voltmeter to the push button switch terminal that is connected to the wire going to the middle of the board. Connect the positive voltmeter lead to the power switch terminal coming from the three-cell power supply. If you get 4.5 volts, proceed by making sure the power switch is ON and connect the positive voltmeter lead to the outside foil of the PCB. If all checks out but you still don't get the power LED blinking or buzzer sounding when you depress the reset switch, you will need to check all of your solder joints.

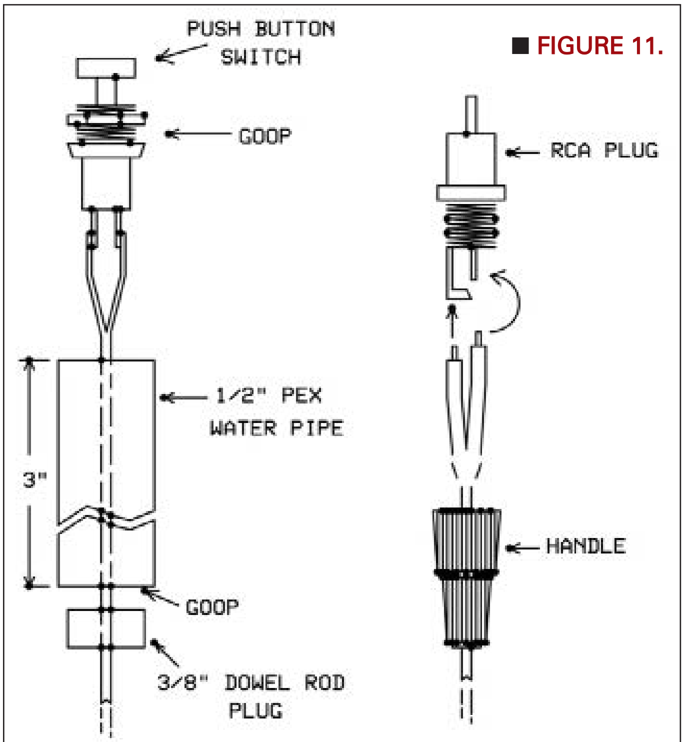
Checking the 10 Student Stations

This can be done at the distribution box. Take an RCA plug apart and temporarily short out the terminals. Replace the plug handle. With the front panel in place and the power and buzzer switches ON, proceed to push the shorted RCA plug into the distribution box jack marked "1." LED lamp 1 should light up at the panel, the buzzer should sound for one second, and the power light stops blinking for about 10 seconds.

Remove the RCA plug and depress the reset push button switch. Now move the shorted RCA plug to Jack 2. LED lamp 2 should light, etc. In this same manner, check all 10 stations.

With the front panel set in place, use a 5/64″ drill to make pilot holes into the 1/2″ x 1/2″ wood pieces that hold the front panel in place. (The front panel is held in place with five #4 x 3/4″ Phillips pan head sheet metal screws.) Wood screws are okay to use.

■ FIGURE 11.



Hand Switch Construction

Figure 11 shows the construction of the hand switch. I suggest that you first make up one complete hand switch to see if you want to change the design at all. Start with the 3/8″ diameter dowel rod plug. Cut the dowel rod so the plug is 1/4″ to 3/8″ thick. Drill a hole at the center for the size of the wire you will be using. Make all hand switch wires 16.5 feet long. Place the wire down through the plug for about 6″. Cut 3″ from a five foot piece of 1/2″ O.D., 3/8″ I.D. PEX water pipe. Using a 3/8″ drill, enlarge each end of the 3″ pipe to a depth of about 1/2″ to better receive the push button switch and plug. Now place the wire through the 3″ pipe.

Remove 1/8″ of insulation from the ends of the wire. Put solder on wire ends and on push button terminals. Sweat wires to terminals. I always use small alligator clips as heatsinks at the base of the switch terminals to protect the switch contacts. Remove the split washer that comes with the switch. Put the nut back on the switch so that several threads show. Put GOOP all around the threads of the switch below the nut. Push the switch into the pipe. With your finger, wipe excess GOOP away such that you are causing the nut to stay tight against the pipe. Next, GOOP the bottom of the pipe. Move the plug into the bottom of the pipe by pushing on the plug while pulling on the wire. Place the switch in a vertical position so that the GOOP will want to run down around the plug and wire. This will keep the wire from twisting inside the pipe.

At the other end of the wire, make the two ends slightly staggered (see **Figure 11**). Remove the handle from the RCA plug and put it over the wire. Put solder on the ends of the wires and at the terminals. Sweat the wires to the terminals. Screw the handle onto the plug. To keep the wire from twisting inside the handle, force some GOOP into the opening between the wire and handle. Give the GOOP at least 12 hours to cure and then try out the switch with the quiz box.

Contact me at: **jlbrittan@netzero.net,** if you need help securing parts for the TestMaster Quiz Box. **NV**

About the Author

John is a retired college Professor with 41 years of teaching. In the late 1950's he went to work in the HeathKit engineering department responsible for the EK-1 ***Basic Electricity*** course. He then developed the electronics for the EK-2 radio project before returning to teaching high school physics and math. In 1969, John accepted a teaching position in electronics at Lake Michigan College. He is now retired with electronics as his hobby.

PARTS LIST

ITEM	DESCRIPTION
Resistors	
Unless noted, all resistors are 1/8W 5% carbon composition.	
❑ R1-10, 36	3.3K (11)
❑ R11-20, 38	1K (11)
❑ R21, 31	10K (2)
❑ R22	22K
❑ R23	220 ohms
❑ R24	118K 1%
❑ R25	487K 1%
❑ R26, 28, 29, 30, 33-35	100K (7)
❑ R27	1.8 meg
❑ R32	220K
❑ R37	100 ohms
Capacitors	
❑ C1	0.01 µF ceramic disc
❑ C2, 3, 4	4.7 µF 10V tantalum
❑ C5	0.001 µF ceramic disc
❑ C6, 7	0.1 µF ceramic disc
Semiconductors	
❑ SCR1-10	Silicon-controlled rectifier TO92
❑ Q1 - 8	2N3904 NPN transistor TO92
❑ D1-11	LEDs, 20-30 mA
❑ D12, 13	1N914 diodes
❑ U1	TLC555

Parts above are available from (**www.allelectronics.com**) except SCR1-10 which is available from (**www.mouser.com** part #511-P0102BA).

QTY	PART #	DESCRIPTION
❑ 10	PPRP - B	RCA plug
❑ 10	RCMJ	RCA jack
❑ 1	DB - 9P	D-sub nine pin (male) connector
❑ 1	DB - 9S	D-sub nine pin (female) connector
❑ 2	MTS - 4PC	SPDT toggle switch
❑ 11	MPB - 1	Red pushbutton switch
❑ 1	1591 - CSBK	Black ABS case and cover
❑ 16 ft 8 inches	566-8457-100	Belden 12-conductor unshielded wire
❑ 10 ft	517-3302/10FT	Color-coded flat ribbon cable (You can use any hook-up wire)
❑ 165 ft	566-6500UE-U500	Unshielded Belden wire for 10, 16.5 ft hand switch cables (or use shielded microphone wire)
❑ 6	561-K6.5	1/2 inch nylon spacer for #6 screw
❑ 1	251-0103	3V buzzer
❑ 1	12BH431D	three-cell AA holder

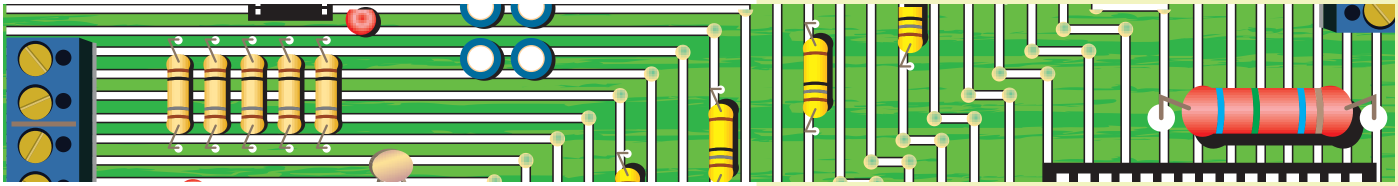
These parts are available from Mouser.

Misc.

❑ 10 hand switch plastic handle, three inches long, made from 1/2 inch O.D., 3/8 inch I.D., PEX water pipe

❑ 6	#6-32 X 1″ screw
❑ 6	#6-32 nut
❑ 6	#6 tooth washers
❑ 5	#4 X 3/4″ Phillips pan head sheet metal screws
❑ 2	#2-56 X 1/2″ screw
❑ 2	#2-56 nut
❑ 2	#2 tooth washers
❑ 1 ft	#20 bare wire

❑ 1 case with lid to house the entire project



Properly Selecting Electronic Components

Part 2

by Vaughn D. Martin

Part 1 covered resistors and their variants — the most common passive components. This time, we'll cover capacitors and inductors to conclude passive components. The next two parts will cover active components.

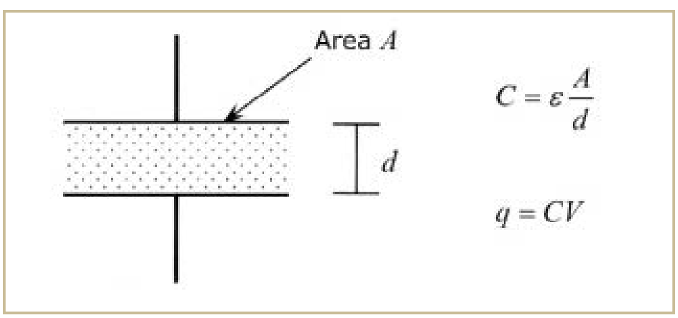


Figure 1. The physical and electrical parameters affecting capacitance.

Capacitors

Capacitors exist in a perplexing variety of physical forms, sizes, and characteristics. A capacitor stores energy as an electrostatic field between its plates. This ability to store an electrical charge is like a "temporary battery" (see **Figure 1**). This formula shows that the dielectric constant □, the spacing between plates *d*, and the area of the plates *A* all determine C or capacitance. Its unit symbol is the Farad (F). Common capacitor values range from microFarads (µF, 10^{-6} F), through nanoFarads (nF, 10^{-9} F) down to picoFarads (pF, 10^{-12} F). Making □ thinner will increase capacitance but the trade-off is less ability to withstand higher voltages since voltages can "push through" the dielectric. There are some self-healing capacitors, however.

Self-Healing Capacitors

Plastic films, like ceramic material capacitors (to be covered), can have pin holes. Metalized film capacitors can eliminate these faults by applying a much higher voltage than the rated voltage. This self-healing produces a "zero defect dielectric." The self-healing process begins as an electric breakdown, which takes about 10^{-8} seconds. The dielectric in the breakdown channel becomes highly compressed plasma that presses the dielectric layers apart as it departs the channel. WIMA in Mannheim, Germany, Easby Electronics in England, and Electrocube in America are companies producing these specialty capacitors.

Unlike batteries, capacitors do not use electrochemical reactions for their source of charge. Placing two metal plates close together and connecting a voltage across them transfers the charge across the plates at a rate dependent upon the applied voltage; see **Figure 1** again. You can really see this better with an air core (dielectric)

capacitor, as in **Figure 2**. This is actually a tuning capacitor often found in old tube radios. This one has four sections ganged together yielding, in effect, four capacitors that you tune in unison.

A dielectric is a nonconductor of electricity, especially a substance with electrical conductivity of less than a millionth (10^{-6}) of a Siemens. A Siemens describes electrical conductance and is equal to one ampere per volt. *Dielectric constant* and *relative permittivity* are synonyms and measure a material's ability to resist the formation of an electric field within it.

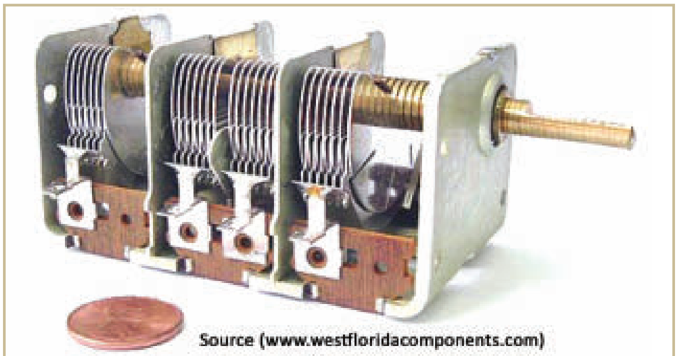


FIGURE 2. An air core capacitor that allows a better 'visualization" of factors constituting a capacitor's capacitance.

Two Fundamental Capacitor Formulae

Charge in Coulombs represents stored energy and is proportional to the applied voltage and the capacitor's capacitance.

Charge is: $Q = C \times V$ *Formula 1*
where Q = charge in Coulombs, C = capacitance in Farads, and V = voltage in volts.

Energy is: $W = E^2 \times C / 2$ *Formula 2*
where W = energy in Joules, C = capacitance in Farads, and E = voltage in volts.

Capacitor Dielectrics

The capacitor's dielectric largely determines its behavior. Capacitor dielectrics fall into two broad categories: bulk insulators and metal-oxide films; the latter is synonymous with electrolytic capacitors. That is why you will often see capacitors described by their dielectrics, such as ceramic, mica, mylar, solid tantulum, or electrolytics. You'll find vast differences in such things as capacitance for a given size, leakage (the conductivity of the dielectric), capacitance versus frequency, voltage and current ratings, variations with temperature, and polarized and non-polarized capacitors.

Leakage current through the dielectric is usually very minute and you can usually ignore it. Since the resistance of the dielectric is extremely high, you can safely assume the dielectric effectively prevents current flow through the capacitor. However, if the leakage current appreciably increases, a rapid loss of charge and overheating occur.

Equivalent Series Resistance (ESR)

This important capacitor parameter is the effective resistance that is not part of the capacitor's pure capacitance. Its principal sources are the capacitor's internal lead and plate resistances. A low capacitor ESR of 0.01 ohms is ideal for high current pulse applications that deliver huge currents into very low impedance circuits (which can be dangerous). A photo flash is a good example. **Figure 3** shows a circuit at turn-on driving a capacitor; the irregularity seen on the scope's trace represents the capacitor's ESR.

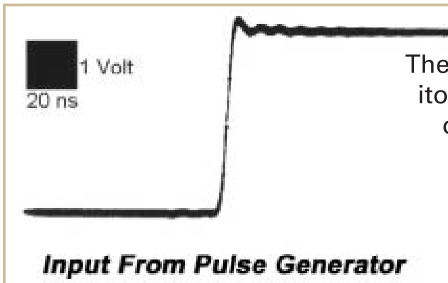


Figure 3. The effect of a capacitor's ESR as viewed on a scope, with a circuit just being powered on showing the signal's ring.

ESR Measurement

You can measure an aluminum electrolytic capacitor's ESR as the resistance of the equivalent series circuit in a measuring bridge supplied by a 120 Hz source free of harmonics, with a maximum AC signal voltage of 1V RMS and no forward-bias voltage (see **Figure 4**). Since a capacitor passes AC only, the bridge will only detect its resistance or ESR. A full wave rectified bridge yields this 120 Hz.

Equivalent Series Inductance (ESL)

The causes of capacitor ESL are the same culprits as in ESR. For any capacitor, there is a frequency at which it ceases to behave as pure capacitance. As we will soon discover, inductors purposely oppose ***changes*** in current. Decoupling capacitors are a must for high speed logic circuits. Without them, the IC demands current faster than the power supply can supply it under rapidly switching

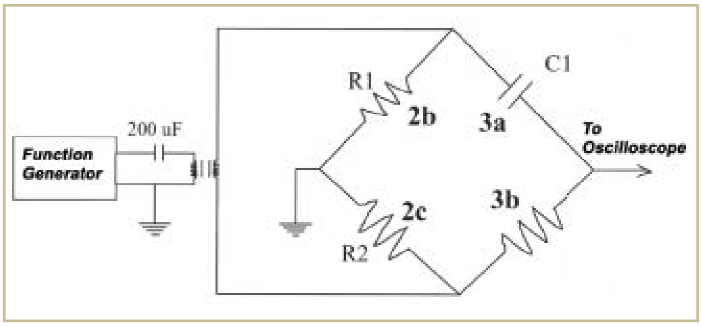


Figure 4. A setup to measure a capacitor's ESR, exploiting the fact that a capacitor passes AC but that the series ESR will represent one of the four legs in this bridge circuit.

conditions. Physically large capacitors have proportionally higher ESL than smaller ones. This is why many electronic circuits commonly use multiple bypass capacitors. A 0.1 µF or smaller capacitor is for high frequencies, and larger electrolytic capacitors are for lower frequencies. You can even encounter an intermediate value capacitor.

Coupling Versus Bypass Capacitor Functions

Borrowing from the common water tower analogy often used to explain Ohm's Law, let's further imagine water flowing through a pipe. Picture a capacitor as a storage tank with an inlet and outlet pipe (see **Figure 5a**).

A "coupling capacitor" connects a signal from one part of a circuit to another by not allowing any DC to flow. If the current flow alternates between zero and a maximum, it allows the current waves to pass through (see **Figure 5b**). However, if there is a steady current, only the initial short burst will flow until the "floating ball valve" closes and stops further flow.

A coupling capacitor allows AC to pass through because the ball valve doesn't get a chance to close as the waves go up and down. However, a steady current quickly fills the tank so that all flow stops (apart from an initial surge). To re-emphasize this point, a capacitor passes AC but blocks DC. Decoupling capacitors "smooth out ripples" by passing them to ground, allowing DC to flow smoothly (see **Figure 5c**).

Capacitor Aging

If you are an audiophile breathing life back into an old piece of audio equipment, swap out all the electrolytic capacitors. Aging causes both the electrolyte and dielectric to deteriorate. If this is too ambitious of a task, try powering up the equipment by first applying a low voltage. This gradually reforms the capacitors. Regardless, deteriorating electrolytic capacitors are the most probable source of hum. Non-polarized capacitors also age poorly, changing their values over time.

Managing In-Rush Current

In high voltage DC applications, you can minimize accumulated capacitor stress due to in-rush currents at circuit power-up with a pre-charge circuit. In-rush currents into capacitive components greatly stress them. When DC input power reaches a capacitive load, the step response of the voltage input charges the input capacitor. The capacitor charging starts with an inrush current and ends with an exponential decay down to the steady state condition. The current into a capacitor is:

$$I = C\,(dV / dT) \qquad \textit{Formula 3}$$

Peak in-rush current depends on the capacitance and the rate of change of the voltage (dV/dT). The in-rush current increases as the capacitance value increases, and the in-rush current will increase as the voltage of the power source increases.

Figure 5a. Current flow is allowed to pass through this capacitor, alternating between zero and maximum amplitude.

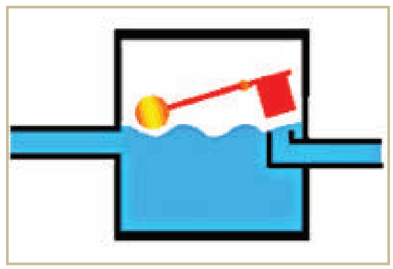


Figure 5b. This shows that if there is a steady current, only the initial short burst will flow until the proverbial "floating ball valve" closes and stops current flow.

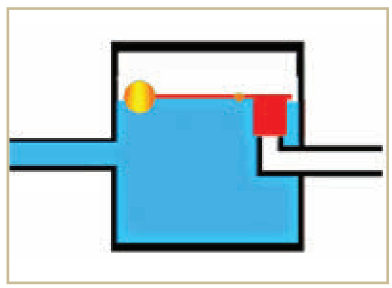
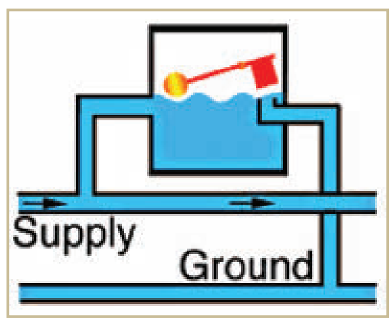


Figure 5c. This is how a coupling capacitor allows "alternating current" to pass through because our perceived ball valve can't close as the waves go up and down.



A pre-charge circuit (**see Figure 6**) limits the in-rush current magnitude into capacitive loads during power-up. This may take several seconds, depending on the system. In general, higher voltage systems benefit from longer pre-charge times during power-up.

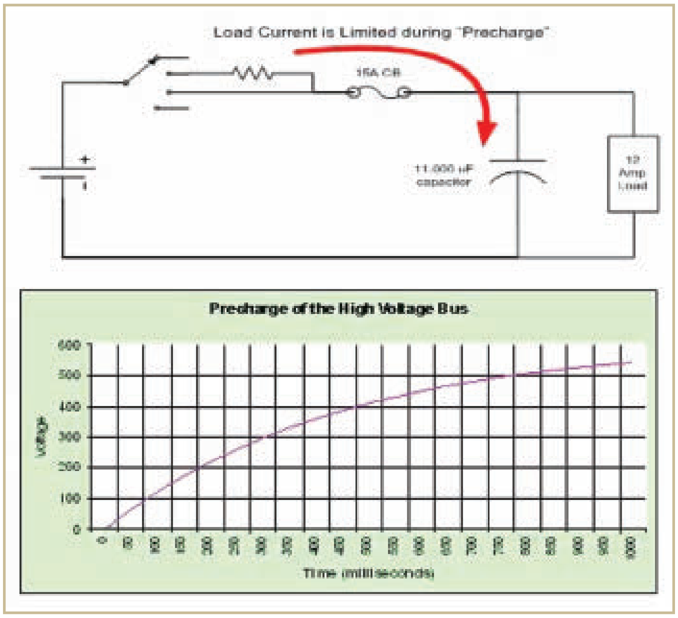


Figure 6. A pre-charge circuit that nullifies the damaging effects of the in-rush current.

> **Breakdown Voltage**
> This limits the power density of capacitors and is proportional to the dielectric's thickness.

The Q Factor

The capacitor "Q" (quality) factor indicates a capacitor's losses. A lower capacitor Q indicates a greater capacitor loss. Aluminum electrolytic capacitors typically have low Q factors. The following link automatically calculates the capacitor's Q factor. The resistance in the monograph is ESR: **www.csgnetwork.com/capqualfactcalc.html**

This next site will give you virtually any formula you need for L, C, and R values you might have on hand: **www3.telus.net/chemelec/Calculators/Calculators.htm**.

Dielectric Absorption

Some dielectrics maintain a "memory" of a high voltage — even after discharged, which they held for a prolonged period. The percentage of retained voltage is the amplitude of the dielectric absorption and is dielectric-dependent.

Capacitor Failure Modes

Capacitors can fail or cause improper circuit operation in four different ways:

1. Change in Value (such as when electrolytic capacitors age)
2. Equivalent Series Resistance (ESR)
3. Dielectric Leakage
4. Dielectric Absorption

Capacitor Values

In the late 1960s, a standardized set of geometrically increasing base values evolved. According to the number of values per decade, these were called the E3, E6, or E12 series. Take a look at **Table 1**. **Table 2** explains their color coding scheme.

Series	Values											
E3	1.0				2.2				4.7			
E6	1.0		1.5		2.2		3.3		4.7		6.8	
E12	1.0	1.2	1.5	1.8	2.2	2.7	3.3	3.9	4.7	5.6	6.8	8.2

Table 1. The cardinal numbers associated with a capacitor's value; only zeros are added to realize the actual value.

Capacitor Color Coding

Color	Significant digits	Multiplier	Capacitance tolerance	DC working voltage	Operating temperature
Black	0	1	±20%	—	-55 °C to +70°C
Brown	1	10	±1%	100	—
Red	2	100	±2%	—	-55 °C to +85°C
Orange	3	1,000	—	300	—
Yellow	4	10,000	—	—	-55 °C to +125°C
Green	5	—	±20%	500	—
Blue	6	—	±5%	—	-55 °C to +150°C
Violet	7	—	—	—	—
Grey	8	—	—	—	—
White	9	—	—	—	—
Gold	—	—	—	—	—
Silver	—	—	—	1000	—

Table 2. The capacitor color coding convention.

Capacitor Types

• **Air-gap:** These capacitors have low dielectric losses and are ideal for tunable capacitors for resonating HF antennas.

• **Glass:** These capacitors are extremely stable and reliable.

• **Paper:** Often found in antique radio equipment, they have up to 25,000V for large oil-impregnated energy discharge types.

• **Polycarbonate:** These make good filters, have a low temperature coefficient, age well, but are expensive.

• **Polyester:** These range from about 1 nF to 1 µF and are ideal signal capacitors and integrators.

• **Polystyrene:** These usually come in small values (picoFarad range) and are stable signal capacitors.

• **Polypropylene:** These low-loss, high voltage signal capacitors are resistant to breakdown.

• **Teflon™ :** These have higher performance and are more expensive than other plastic dielectrics.

• **Silvered Mica:** These are fast and stable for HF and low VHF RF circuits, but expensive (see **Figure 7**).

• **Electrolytic:** These capacitors have a larger capacitance per unit volume than other types but, as previously mentioned, are limited to low frequency electrical circuits, e.g., in power supply filters or as coupling capacitors in audio amplifiers.

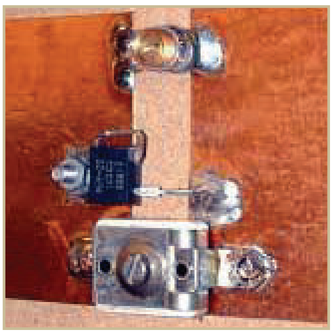


Figure 7. A silver mica capacitor used in a resonating HF antenna circuit.

Ultra-Capacitors

Now to contradict myself, an ultra-capacitor is indeed like a rechargeable battery. It stores a huge charge proportional to its capacitance. It differs from an electrolytic since it uses electrical double-layer architecture. **Figure 8a** shows the standard electrolytic architecture with a dielectric substrate sandwiched between two electrodes. **Figure 8b** shows that it is wound around like a jelly roll. **Figure 8c** shows the materials used in an electrolytic capacitor. A surface mount (SMD) capacitor also has layered dielectrics and electrodes; however, it does not use the superior material and technologies (discussed next) inherent in super-capacitors (see **Figure 9**). Electric double-layer ultra-capacitors add a second dielectric layer that works in parallel with the first layer (see **Figure 10**). This extra layer

Figure 9. An SMC capacitor that used fused layers of both its dielectric and its electrodes.

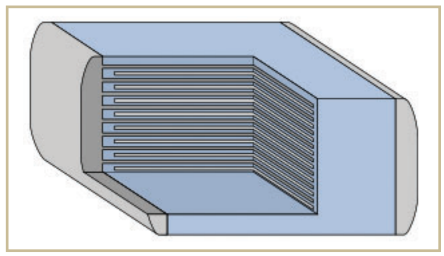
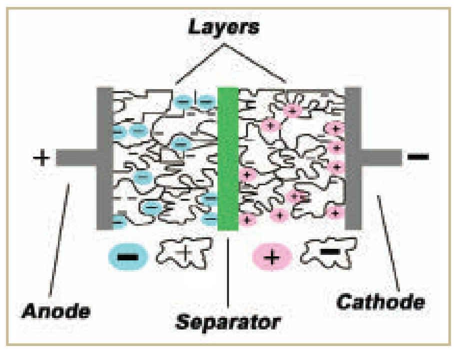


Figure 10. The basic technology in an ultra-capacitor that uses special dielectrics and layers of materials very effectively to realize 10,000 times more capacitance per unit area than its brethren.



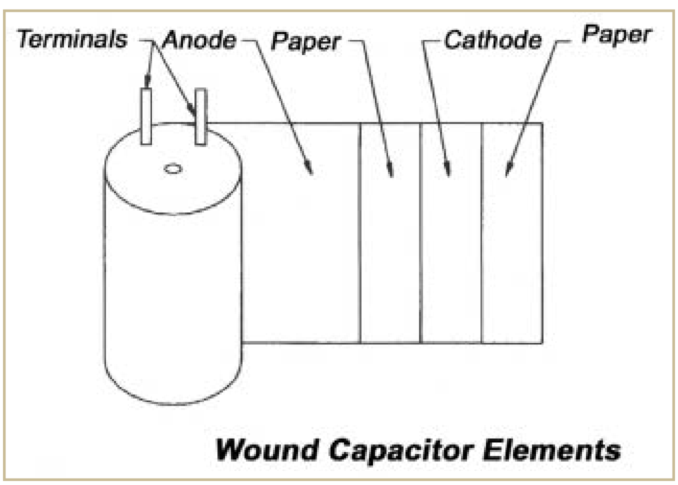


Figure 8a. An electrolytic capacitor's architecture.

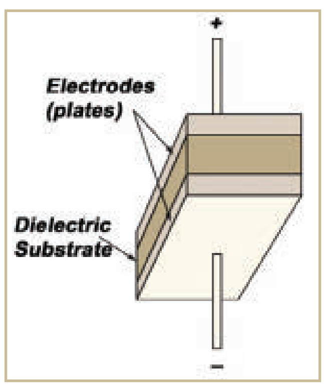


Figure 8b. A different view of an electrolytic capacitor's construction.

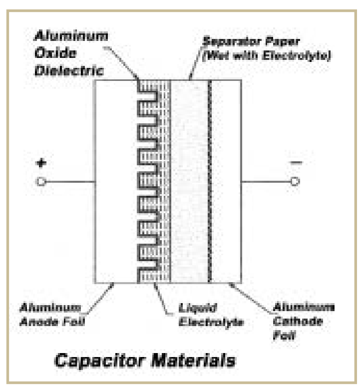


Figure 8c. Typical materials manufacturers use in electrolytic capacitors.

Figure 11. A 0.3 Farad (not µF) capacitor no larger than a quarter!

combined with more efficient dielectrics boosts capacitance approximately four orders of magnitude. Note how small the ultra-capacitor in **Figure 11** is. It is a 0.3 Farad capacitor about the size of a quarter. More seasoned readers may recall calculating the volume of a 1 Farad capacitor using realistic parameters. It usually ended up being about the size of an office desk.

Ultra-capacitors have numerous benefits over rechargeable batteries:

- More charge/discharge cycles
- Efficiencies near 98%
- Lower internal resistance
- Higher output power
- Better thermal capabilities

Inductors (Also Called Coils)

These are wires wrapped around a magnetic material in a coiled fashion. The letter L symbolizes inductance. Its unit symbol is the Henry (H), and its schematic symbol is appropriately a coiled wire (see **Figure 12**). A resistor merely opposes (restricts) current flow, whereas an inductor opposes a ***change*** of current flow. That is its advantage and why old-timers called them "chokes." An inductor develops a voltage across the coil with a polarity opposing any changing current. Driving an inductor with a sine wave voltage causes the inductor's current to constantly change. Inductance relates this induced voltage to the current. **Figure 13** shows an assortment of air core inductors.

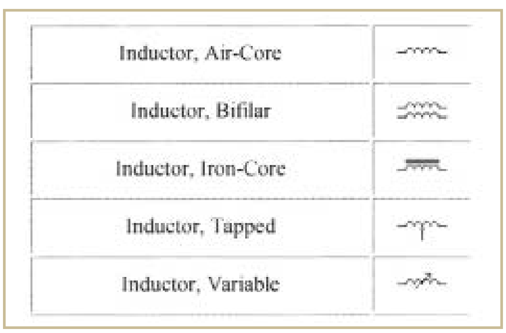


Figure 12. The various schematic symbols for inductors.

Exploiting An Inductor's Salient Characteristic

Lighting LEDs from a single 1.5V cell is difficult since a red LED's forward voltage alone is about 1.8 VDC. You can still accomplish this by using an inductor to your advantage (**see Figure 14**). This classic astable produces a square wave and Q_2's collector switches Q3. When Q3 turns on, it charges the inductor L_1. After it switches off, the inductor discharges its stored energy through the LED during flyback, and it lights the LED.

Inductive Flyback Or Kickback

This is the very rapid change in voltage across an inductor when you interrupt current flow. This causes a realized voltage greater than the supply voltage. This is the principle of a TV's kickback transformer.

Since inductors oppose changes in current flow, you may wonder, could I use them in high speed serial data transmission? Excessive impedance in traditional non-air-core common mode geometries in ordinary inductors prevents this. This compromises signal integrity in transmission. Firewire and USB2.0 are clocked at greater than 480 Mb/s. Several companies — such as Steward — have developed unique inductor geometries for Firewire and USB2.0 that minimize impedance at 500 MHz. This even allows undisturbed passage of video

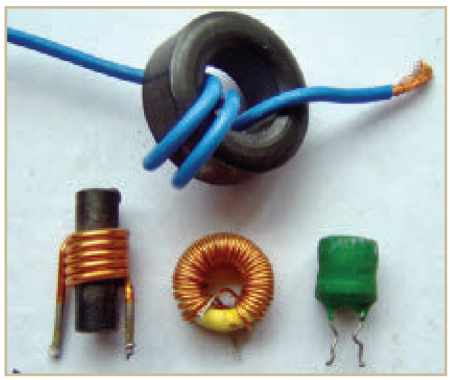


Figure 13. An example of air core inductors showing their primitive windings.

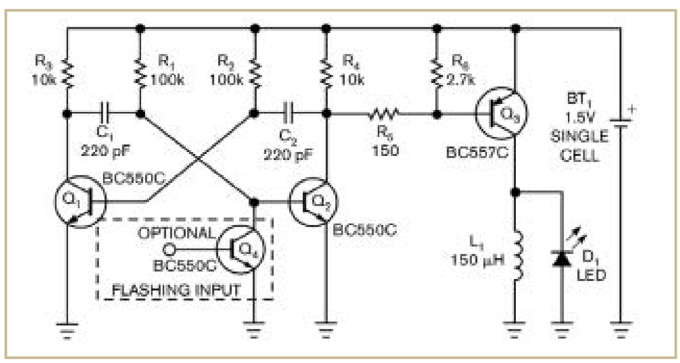


Figure 14. A circuit that uses the flyback principle inherent in an inductor to step up the voltage to an extent allowing the 1.5 VDC battery to run a red LED.

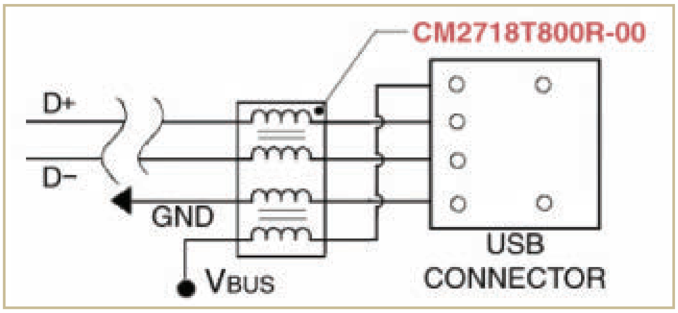


Figure 15. A special SMD coil that minimizes its ESR and current blocking tendencies so that it can drive high frequencies — even video — without signal degradation.

signals while maintaining picture quality. **Figure 15** is a surface mount special geometry Steward coil used in a USB application. With the exception of varistors covered in Part 1, coils are the only passive component that can exhibit pronounced non-linear characteristics. They are passive because they cannot generate energy. Values range from fractions of milli-Henrys to fractions of Henrys. You can temporarily store energy in magnetic fields and inductors. Dramatic examples are an inductor firing a spark plug, and to a lesser extent, our LED example. Inductors, like capacitors, have ESR. **Figure 16** shows its effect as seen on a scope as a pulse generator drives a circuit.

Inductor Frequency Ranges Versus Structure And Core Materials

As previously mentioned, coils may use a metallic core center. As a rule of thumb, use iron cores for frequencies below 100 kHz. Use ferrite cores for frequencies in the 10 MHz range; above 100 MHz, the core is usually air and the coil is structurally self-supporting. Check out **file:///F:/air%20coils/Air-Core-Inductor-Calculator.phtml.htm** for an electronic monograph to calculate air core coil inductance.

At low frequencies, an inductor may have hundreds of turns, but above 1 MHz they only have a few turns. Most inductors have a low DC resistance since they are wound from copper wire. You will often see them if you look under the amateur radio section cores and coil winding machines of varying degrees of sophistication on eBay (see **Figures 17** and **18**). **Figure 19** shows a cut-away exploded view of a toroid or device that goes on a coil winder that holds the wire.

A monograph is a special graph with three lines purposely graduated that allows a straight line to intersect any two of the lines of the known values' intersects. The third line crossing them is the value of the related unknown variable.

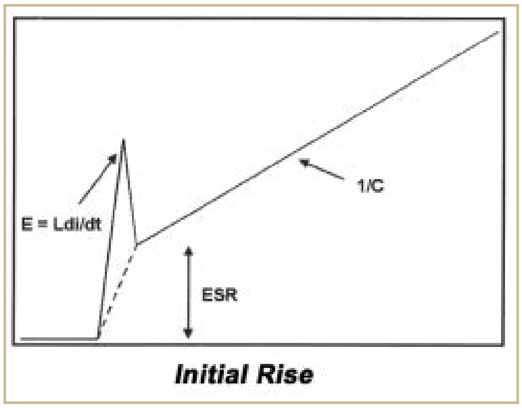


Figure 16. A scope trace of an inductor with ESR being driven by a pulse generator.

Figure 17. A manual coil winding machine.

Figure 18. A slightly more sophisticated manual coil winding machine that also holds bobbins.

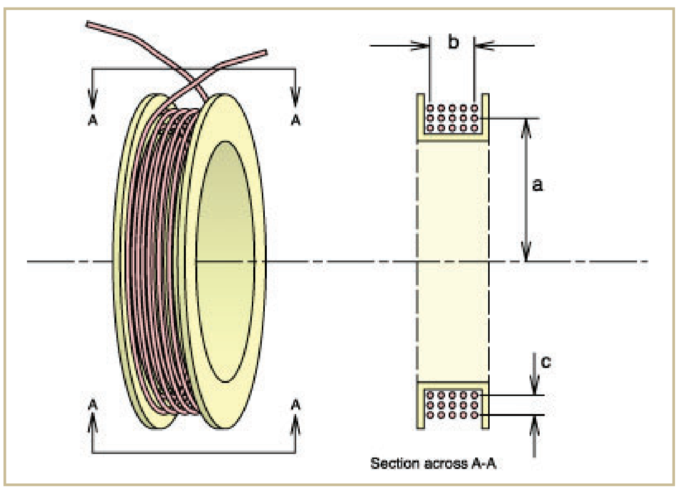


Figure 19. A close-up/cut-away view showing what a winding on a bobbin (wound indicator) looks like.

Rolling Your Own

What if you decide to make your own coils? You can empirically use trial and error or arrive at a very close approximation of your desired value by using a formula from an old 1928 IRE (Institute of Radio Engineers) proceedings:

$L = (0.394 * r^2 * n^2) / (9r + 10b)$ µH
Formula 4

where:
L = inductance in µH.
r = radius of the coil (in cm).
n^2 = number of turns in the coil squared and;
b = the length of the coil in cm.

Optimizing Q

A coil's Q is actually dimensionless. The "Q" is a very important property of both capacitors and inductors. The Q of capacitors is generally so high you can usually ignore it. However, an inductor's Q results from it having some extra resistance to AC or RF. The Q is the reactance divided by this AC or RF resistance plus the DC resistance of the windings.

The formula for Q is:
$Q = (2 * pi * f * L) / R$
Formula 5

A much better formula for a coil's inductance is: (where coil length = diameter [which is best for optimum Q]), is as follows:

$N = [29L / 0.394r]^{1/2}$ OR
$L = [(0.394 * r * N^2) / 29]$
Formula 6

where:
N = number of turns
L = inductance required in µH.
r = radius of the coil (in cm).
29 and 0.394 are constants to simplify this formula
[Formulas 4, 5, and 6 are from Ian Purdie's amateur radio tutorial page.]

Using Components In Circuits

Placing resistors in series adds their values; placing them in parallel reduces their resistance, but increases their current carrying ability. Capacitors in series act like resistors in parallel whereas in parallel capacitors add since you are effectively increasing the area of their plates. Inductors in series add like resistors, but in parallel the following formula describes that.

Inductors in Parallel

The formula $L_T = [1 / L_1] +/- M + [1/L_2] +/- M$ where L_T is total inductance, L_1 is the first inductor, and L_2 is the second inductor; both are in parallel. The term M stands for mutual inductance and indicates whether the magnetic fields are adding or subtracting from each other. If they are subtracting, they tend to cancel each other out. This is the basis of the concept of bifilar windings.

Tune in next month for active components. **NV**

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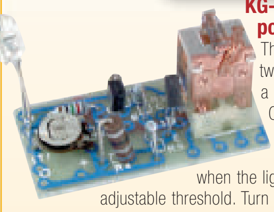

This kit can operate as a twilight on/off switch or as a light trigger relay. Operated from 12 volts, this versatile project triggers a 6 amp relay when the light intensity falls below an adjustable threshold. Turn lights on around the house when it goes dark or trigger an alarm when a light is switched on. Kit supplied with Kwik Kit PCB, relay and all electronic components.

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Learn everything there is to know about component recognition and basic electronics with this comprehensive kit. From test leads to solder, everything you need for the construction of this meter is included. All you'll need is a soldering iron!

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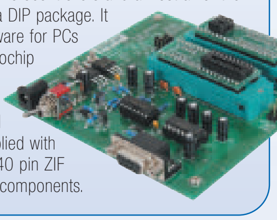
This very cost effective programmer kit can handle all the DSPIC30F family of PIC microcontrollers and almost all of the regular PICs available in a DIP package. It uses freely available software for PCs and is easy to build. Microchip offers free documentation and source code on their website so getting started should be a breeze. Supplied with screen printed PCB, 2 x 40 pin ZIF sockets and all specified components.



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Experiments with Alternative Energy

Part 1 - Solar Energy

By John Gavlik, WA6ZOK

Welcome to this first article on Experiments with Alternative Energy. As an electronic engineer (Cal Poly, Pomona, CA), I've always been interested in renewable energy, so to promote it as a topic for teaching and learning math and science in K-12 schools and colleges, in 2002 I founded my company LearnOnLine, Inc., and created the REEL Power (Renewable Energy Education Lab) project. These experiments are based on that effort.

Our first lesson is on solar energy and how you can measure DC electricity under various series and parallel wiring configurations, loads, and light sources. Future articles and experiments will address more on solar energy plus wind turbines and fuel cells. I wanted to include experiments on geothermal, biomass, and ocean wave devices, but these are a bit too difficult to perform on a desktop.

We'll begin with the fundamentals of how to set up the "test bed" — the hardware, firmware, and software — along with the data acquisition and data display techniques. The important point to realize is that you will be able to work with either a Parallax BS2 or PICAXE 28X2 microprocessor along with the supplied basic language code for each of them. The code and the component setups are designed to give you a highly detailed insight into how solar panels, wind turbines (three-phase, no less), and fuel cells operate on an electrical basis.

In the experiments, I will touch on elements of mechanics, physics, and chemistry to round things out where necessary. However, I will walk a fine line between making things too simple or overly complex in terms of the inner-workings of these devices (read no heavy duty math or cumbersome theory — just the basics like Ohm's Law and first year Algebra). So relax. This is meant to be both fun and informative. If you want to learn more (I hope), there are always schools, online forums, and the web.

One more thing before launching ahead — most of the details for the equipment setups, the firmware, and graphic software, and especially the experimental procedures are found on my website at **www.learnonline.com**

Figure 1. Experimental Test Bed for the Parallax BS2 Processor.

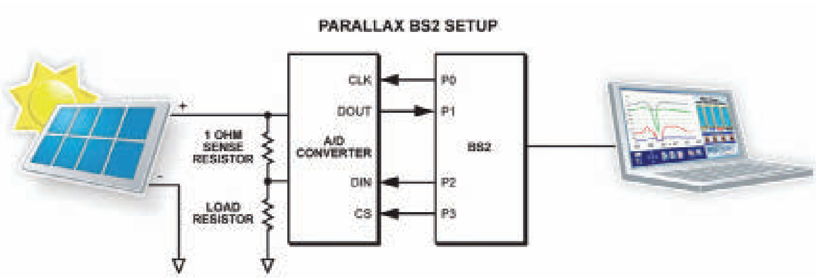
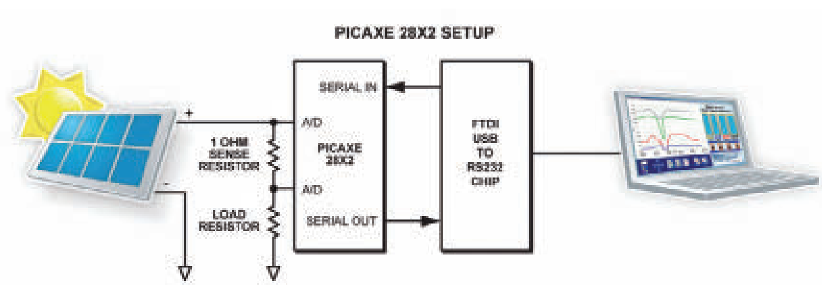


Figure 2. Experimental Test Bed for the PICAXE 28X2 Processor.



under Experimenter Kits. It would be too much of a task to attempt to cover all the necessary material in print form. This and subsequent articles cover just the basics; you can get the full information on the website.

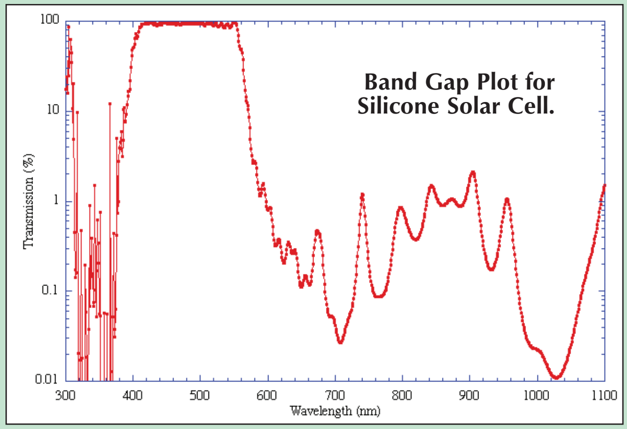
Reference Design

In engineering parlance, there is a term for the experiments presented in these articles. It's called a "reference design" because while a reference design works and does the job it is meant to do, it is not optimized for speed, cost, performance, efficiency, clever extra features, etc. That's why I'm leaving it up to you to take what is offered in terms of hardware, code, and technical approaches to come up with something more personal in terms of what you would like to see the experiments do. I've attempted to make them as complete and open-ended as possible to do this, so I encourage you to put your personal mark on them and then share what you have with me and your fellow experimenters. That's where the fun and satisfaction is anyway — doing it your way and not just following some rote procedure from someone else's design approach — including mine.

Choose Your Processor and Component Setup

The experiments for the Parallax BS2 or PICAXE 28X2 microcontrollers are exactly the same. The only difference is in the Basic language code and components, so pick the one you are most familiar and comfortable with using and let's get started. The general hardware setups are shown in **Figure 1** for the BS2 and **Figure 2** for the PICAXE 28X2. In order to examine the voltage and current output of a solar panel, we need a suitable A/D (analog-to-digital) converter. Since the BS2 doesn't have one, I've chosen a 12-bit model made by Microchip (model MCP3208) that handles the job nicely. The PICAXE 28X2 — one of the newer PICAXE models — has nine 10-bit A/D converters on board so that's not an issue. The PICAXE can be interfaced directly to the computer's serial port; however, I have chosen a USB-to-RS232 converter chip made by FTDI that is nicely packaged by SparkFun on a small PC board. This not only provides good serial communications but the USB connection generates a stable +5 VDC power source for the PICAXE and the A/D converter's reference voltage.

For both setups, you will notice a one ohm "sense resistor" in series with the load resistor. This is to measure current using the voltage drop across it. We'll get into how this is accomplished shortly. Also notice that both setups are connected to a computer for real-time graphic display of voltage, current, power, and load resistance. Seeing these electrical parameters as simply numbers flowing out of the BS2 or PICAXE in debug mode is totally inadequate



Solar PV Materials

Although silicon is the most common type of material used for PV cells thus far, other materials with more promise are also being used, such as:

- Gallium arsenide (GaAs)
- Copper indium gallium (di)selenide (CIGS)
- Cadmium telluride (CdTe)

The choice of PV materials is important since each type of material including silicon has a different "band gap" which means that it absorbs different wavelengths of energy. Think of the term band gap as a typical analog "band pass filter" that allows only certain frequencies to pass through and blocks others, except the frequencies are much higher. The ideal PV solar material would have a nearly "flat" band gap to allow all visible light and possibly other frequencies beyond the visible light spectrum to pass through and generate power.

This is not a formal definition of band gap but the implication is clear enough — materials that absorb more of the sun's energy produce more electrical power. A material or combination of materials that will improve a solar panel's efficiency is where research is focused.

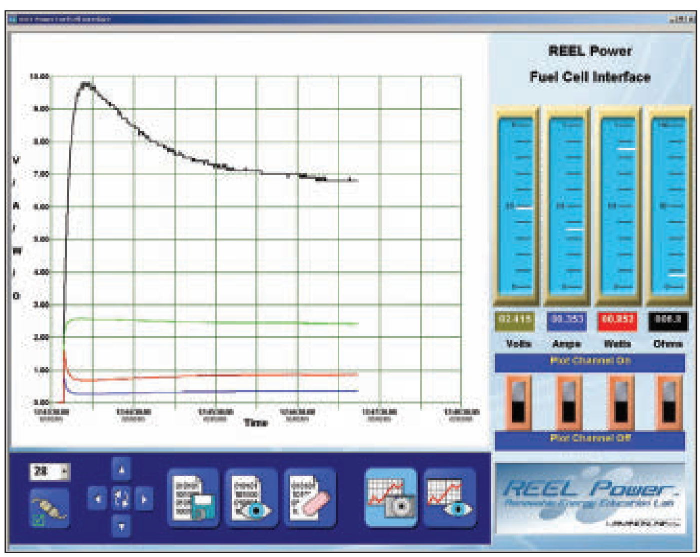


Figure 3. Graphic Software Screen Shot.

for a true understanding of how external factors affect the solar panel's output. The graphic software instantly displays how all the electrical parameters react together; a picture is worth 1,000 words (or 1,000 numbers, in this case).

PC Graphic Software

A common element in all the experiments is the graphic software that displays real-time voltage, current, power, and resistance data coming from the BS2 and PICAXE as plots and numeric data on your Windows PC (**Figure 3**).

As you can see, there is a large graphic area where voltage (green), current (blue), power (red), and resistance (black) are plotted. To the right are four vertical gauges that display these same quantities in both bar-graph and numeric form. Below each gauge is a switch that you can click to turn a particular plot ON or OFF in order to eliminate screen clutter.

Below the plot and meter areas (**Figure 4**) are controls to:

- Select-Connect-Disconnect to the proper com port to receive serial data.
- Horizontal and vertical scale arrow adjustments.
- Clear the plot display area (icon in the center of arrows).
- Start-Stop, Save, View, and Erase logged data in Excel compatible format.
- Capture and View and Save screen snapshots as jpg images.

While the graphic software is a cost item like the micros and other components, at $39 it will do all the experiments for solar, wind, and fuel cells, so one purchase will fill the bill for everything these articles will address both now and in the future.

The Solar Panel

The solar panel chosen for these experiments (**Figure 5**) is both unique and inexpensive for its overall capabilities (about $16 or less). It is really three solar panels in one enclosure, and the three panels can be wired in series and parallel combinations with screw terminals on the back to produce voltages and currents from 1.5 volts @ 300 mA to 4.5 volts at 100 mA. You are

Solar Cell.

Solar Cell Characteristics

Regardless of their physical size, common solar cells like those made from silicon produce approximately 1/2 volt. However, the physical size determines the amount of current that can be produced. As such, solar cells need to be wired in series-parallel arrangements to create the necessary voltage and current characteristics.

Solar cells are like magnets. When you break a magnet in half, both halves still have a North and South pole. If you break a solar cell in half, both halves will still produce 1/2 volt. However, the current for each cell will be proportionally equivalent to the break. The same is true for the gauss producing capabilities of a broken magnet.

Figure 5. Suggested Solar Panel.

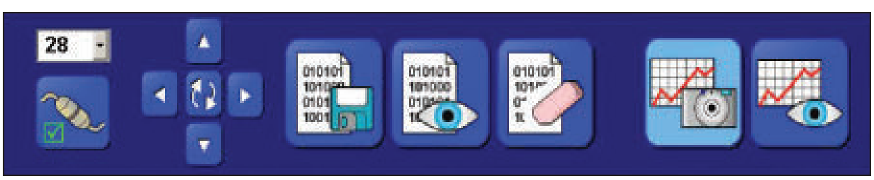


Figure 4. Graphic Software Controls.

Experiment Components

Rather than listing them here, you can find a list of recommended parts on the LearnOnLine website at **www.learnonline.com**. Click on Experimenter Kits.

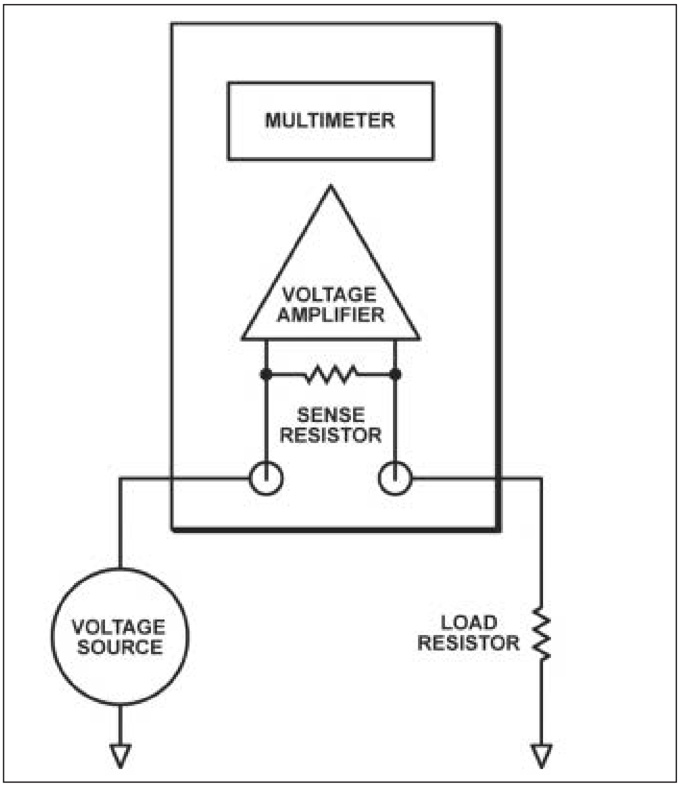


Figure 6. Multimeter Block Diagram for Measuring Current.

free to use your own solar panels, but make sure they do not go over five volts open circuit or else you will swamp the A/D converter chip or PICAXE microprocessor's A/D inputs and perhaps damage them. Refer to the Experiment Components sidebar for your source.

Measuring Current with Voltage Drop

Current is always measured using the voltage drop across a sense resistor. This is true even in the best multimeters. Once you understand this principle, you will have more appreciation for and understanding of the technique.

When measuring current with a normal multimeter, you must interrupt the circuit by placing the multimeter between the voltage source and the load as shown in **Figure 6**. What you are actually doing is placing a very small [value] sense resistor in series with the load. The multimeter measures the voltage drop across the sense resistor using an A/D converter much like the one we are using for the experiments. Based on Ohm's Law, its internal microprocessor computes the current as follows:

$I = V / R$

where I = current in amps
V = voltage in volts
R = resistance in ohms

In order to determine the voltage drop, the multimeter senses the voltage at both places on the sense resistor — at the voltage source and at the load. The current is then computed based on the voltage drop across the sense resistor as follows:

$I = V / R$

where $V = V_{source} - V_{load}$
R = sense resistor value

In modern multimeters, the sense resistor is typically well below one ohm in order not to add to the load.

Solar Panel History Time Line

1839 Edmund Bacquerel — a French physicist who studied the solar spectrum, magnetism, electricity, and optics — is known for his work in luminescence and phosphorescence. He discovered the photovoltaic effect which is the basic physics behind the solar cell.

1877 Later in the 19th century while investigating this effect, Adams and Day noted an anomaly they thought could be explained by the generation of internal voltages. They made selenium cells that were 1-2% efficient.

1904 Albert Einstein — most known for this Theory of Relativity — published a theoretical explanation of the photovoltaic effect. In 1916, Robert Millikan experimentally proved Einstein's theoretical explanation.

1916 The Czochralski method is the technology used to grow the large crystals required in today's chip industry. The method was named after the Polish scientist Jan Czochralski who discovered it by serendipity after accidentally dipping his quill into a tub of molten metal instead of an inkpot. Accidents are the basis for many scientific discoveries.

1950s The first attempts to commercialize solar panels are begun prompted by prior research during World War II for military applications. Once again, the government is needed to fund basic research into new technology in order to spin off commercial applications.

1958 The first commercial solar panel is used with NASA's Vanguard I satellite. The panel was manufactured by Hoffman Electronics, a major commercial and military electronics firm now essentially out of business.

1980s Solar panels are first used in conventional consumer applications for powering calculators, digital watches, battery chargers, and even small buildings.

1990s More efficient solar panels are developed using materials other than silicon. Mechanical solar tracking devices gain popularity to increase total power output.

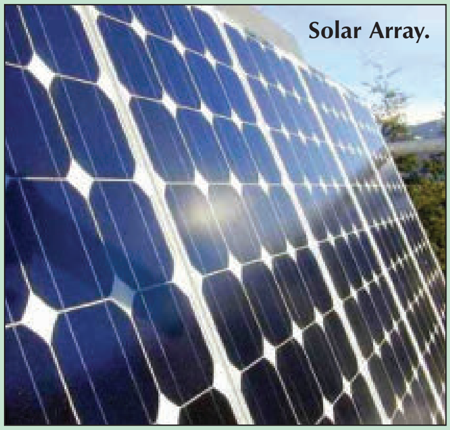
2000 to present Solar energy's promise of independent, grid-free power is slowly becoming a reality. High cost and low efficiencies below 25% are still the major issues.

This value is generally 0.01 to 0.05 ohms — 10 to 50 milliohms — hardly anything in terms of adding to the load resistance. However, with such a small sense resistor the voltage drop is also small. To compensate, the multimeter adds a voltage amplifier across the sense resistor to boost the voltage to a measureable quantity for the A/D converter.

The gain of the voltage amplifier is used in calculating the voltage drop and resulting current value. So, if the voltage drop across a 0.01 resistor is one millivolt and the gain of the voltage amplifier is set at 100, the

Solar Panel Construction

Individual solar cells are wired together in series-parallel arrangements to create the voltages and currents necessary for the solar panel's application. This requires creating a grid of wires and supporting metallic traces for the interconnections which add to the area and also contribute electrical losses like any wires do in a DC circuit. The wires and traces also block light. Modern solar panels incorporate protective diodes that help prevent heavy current overloads if a portion of the panel is shaded. While effective, the diodes create their own electrical losses in terms of normal voltage drop and generated heat.


Solar Array.

Solar cell and solar panel images courtesy ***Wikipedia.com***

The Experiments

Now, let's get started on two of the solar panel experiments. You can find complete details on these and the other experiments including background information, equipment setup, and experiment procedures at www.learnonline.com. Just click on the Experimenter Kits menu selection. Then click on the selected experiment for your chosen processor.

Solar Experiment #1: Sunlight versus Artificial Light

This experiment demonstrates the difference between sunlight and artificial light as it strikes a solar panel. It shows that sunlight provides a constant source of voltage and current while artificial light produces "ripples" due to its AC nature. The ripples are a result of the 60 Hz AC that powers the incandescent light bulbs and fluorescent lights.

Procedure:

Aim the solar panel at an open window with the sun shining (**Figure 7**). Notice the steadiness of the voltage output. Now expose the solar panel to artificial light from an incandescent bulb or overhead fluorescent light. Notice the ripples on the panel's output. This is due to the 60 Hz AC that powers the artificial light. Go back to the window for another look at the steady voltage levels.

Now, expose the solar panel to a higher intensity of artificial light by moving it closer to the light source (**Figure 8**). Note the expected increase in voltage, as well as the increase in ripples. This is a simple experiment, but few people have ever seen artificial light and sunlight measured this way — this may include you, too.

Figure 7. Solar Panel Output for Sun and Artificial Light.

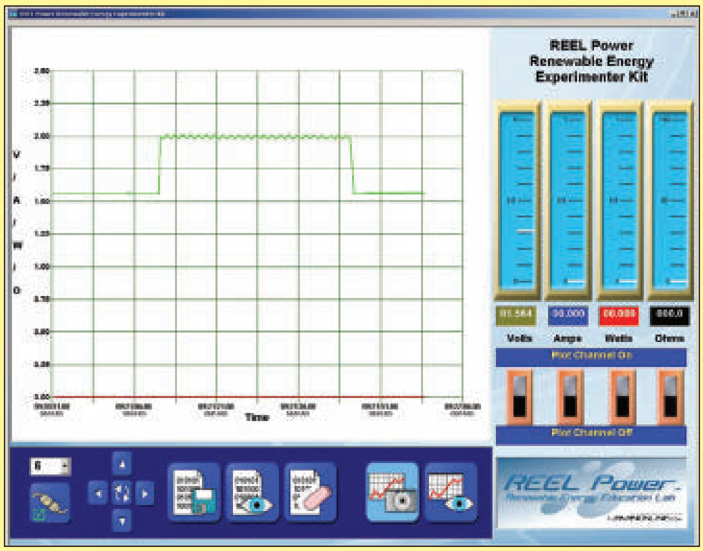
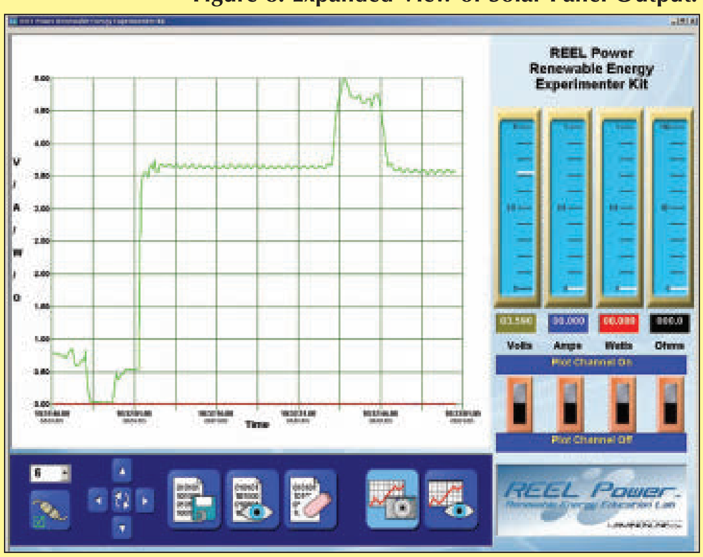


Figure 8. Expanded View of Solar Panel Output.



A/D converter receives a voltage of 100 millivolts that is well within the limits of a good A/D converter.

For our experiments, it was decided to save on the cost and complexity of a voltage amplifier and go, instead, with a one ohm sense resistor. If the actual load resistance is also low (like 10 ohms, or less, as in most of these experiments), there is ample voltage drop across the resistor — especially when applied to a 10- or 12-bit A/D converter which can measure down to 4.88 and 1.22 millivolts, respectively, with a +5 volt reference.

The downside to using a one ohm load resistor is that it adds to the load itself. So, for a 10 ohm load and a one ohm sense resistor, the total load is actually 11 ohms. Therefore, be aware of the fact that the resistance values displayed on the computer are the "sum" of the one ohm sense resistor plus the actual load resistance.

Conclusions

This first brief look into solar photovoltaic experiments gave you a glimpse into what desktop solar panels are capable of doing and how their performance is measured. Commercial solar panels behave in much the same way which is one of the main points of these experiments; that is, to make the connection between what you learn in model form in order to apply the same techniques to real-world systems.

Next time, we will investigate the effects of tilt angle, heat, and shading on solar panels which will give you even more background information. In the meantime, conserve energy and "stay green." **NV**

Experiment #2: Determining the Maximum Power Point

This experiment demonstrates how solar panels in either series or parallel have a maximum power operating condition known as the Maximum Power Point or MPP. The maximum power point is where the solar panels can deliver the maximum power into a load. MPP is a dynamic condition that varies based on external influences such as light intensity, tilt angle, heat, and either a series or parallel arrangement of the panels. You are shown that the MPP is achieved when the resistance of the solar panels matches the load resistance. You will discover this when you vary the load resistance to produce maximum power with solar panels in series and parallel configurations. Satellites in space must constantly adjust their solar arrays to acquire the MPP, which is why this is such an important concept to understand.

Procedure:

Wire the solar panels in series and adjust the 100 ohm potentiometer from full resistance to a lower resistance until the maximum power is reached. Continue to adjust it for lower resistance to see what happens. Then, rotate it back to the maximum power level. A plot similar to the one in **Figure 9** is displayed. Notice the large dip in voltage, current, and power as the heaver load resistance overwhelms the solar panel's ability to source power.

Next, wire the panels in parallel and repeat the same procedure with the potentiometer. While the voltage is noticeably lower due to the parallel wiring configuration, the voltage does not dip as much and the output current and power remain much steadier under the varying load (**Figure 10**). Thus, solar panels in parallel have a better means to supply more stable power over varying loads as compared to an equivalent series arrangement.

Figure 9. MPP for Solar Panels in Series.

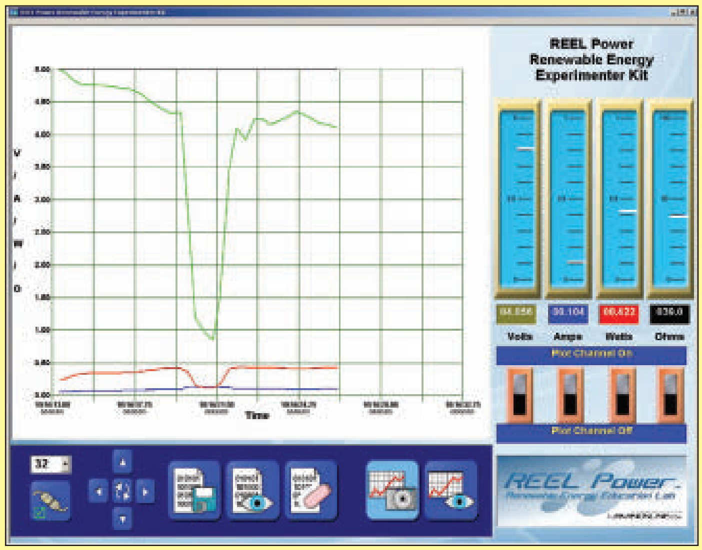
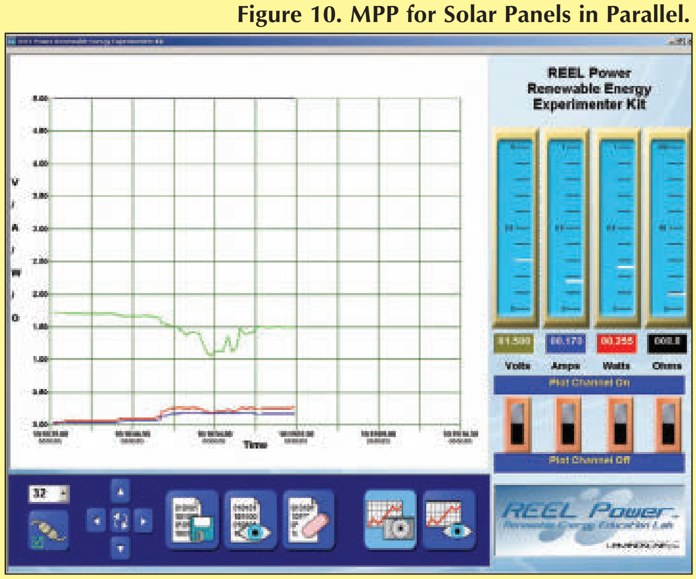


Figure 10. MPP for Solar Panels in Parallel.



THE DESIGN CYCLE

ADVANCED TECHNIQUES FOR DESIGN ENGINEERS

■ BY FRED EADY

USB TO ETHERNET USING MICROCHIP'S FREE STACKS PART 1

When it comes to electronic projects, I'm a mountain man. Despite the proliferation of manufacturer and third party demo boards out there, I prefer to write my own code, design my own printed circuit boards, and take my chances with a soldering iron. This month, the mountain man is coming to town as the coders at Microchip have put together a brand new TCP/IP Stack to support the new Ethernet ICs and wireless Ethernet modules that are coming out of the pipe.

If you've had the chance to read some of the most recent Design Cycle columns, you know we've been exploring the possibilities of replacing embedded RS-232 interfaces with USB interfaces. Although his first love is Ethernet, the Microchip USB coding crew has attracted the attention of the mountain man.

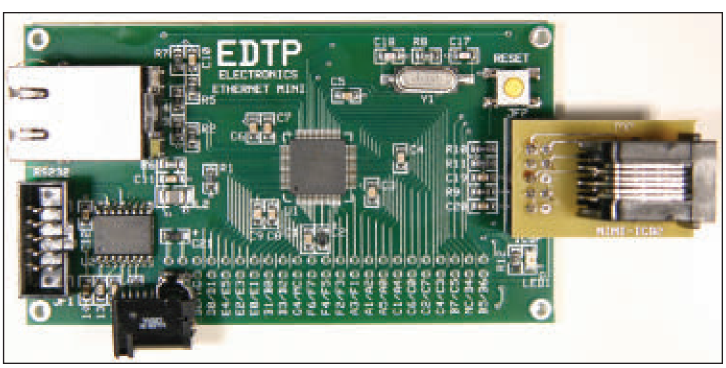
Now, he doesn't come into town very often, so we must make the most of this trip. Our goal this month is to place a PIC18F14K50 low pin count USB device in front of a Microchip PIC18F67J60 standalone Ethernet controller. The resulting Serial-to-Ethernet hardware will be driven using Microchip's free USB Framework and TCP/IP Stack which has enticed the mountain man to leave the forest.

TOOL CHAIN CHANGES

Although Microchip has acquired HI-TECH Software and its family of C compilers, as of this moment Version 5.00 of the Microchip TCP/IP Stack can only be compiled using Microchip's legacy C compilers. So, instead of the HI-TECH PICC-18 code you normally see in this column, this month I'll be dishing out a different flavor of C in the guise of Microchip's C18 Compiler.

I'll also be moving on to a different Ethernet sniffer platform. Due to its high cost, many of you have requested that I move away from the commercial sniffer product I've used in past columns and networking books. I listen to Design Cycle readers and from this point on, the new Ethernet sniffer standard for this column will be the Wireshark Network Analyzer. Wireshark is free for a download from **www.wireshark.org** and is just as powerful as its commercial counterparts. Another plus for Wireshark is that it is extremely easy to learn and operate. I'll run a copy of the Wireshark Network Analyzer on a Lenovo S10 NetBook and provide network captures for you as necessary during our discussion.

The PIC18F67J60 is supported by every Microchip programmer that is currently in production with the exception of the PICkit 1. The same PIC18F67J60 compatibility environment holds true for current Microchip debugging hardware. I have chosen to use the REAL ICE programmer/debugger to support this project. With that, gather up the tools that will form your personal tool chain and let's get started.



■ PHOTO 1. You can get the Ethernet MINI schematic from the downloads area of the EDTP Electronics website. Note that I've attached a circular power jack and programming dongle in this shot. I'll power the MINI with a regulated 3.3 volt wall wart.

THE ETHERNET HARDWARE

Many of you are familiar with the EDTP Packet Whacker, which is a Realtek-based Ethernet NIC. The classic Whacker Realtek device led the way to a new

NIC project built around the Microchip ENC28J60 Ethernet controller called the EDTP Frame Thrower. If you're EDTP Ethernet NIC challenged, you can still get the complete project packages for the Packet Whacker (**www.edtp.com/whacker_page.htm**) and the Frame Thrower (**www.edtp.com/ft_page.htm**) from the EDTP Electronics, Inc., website.

If you take the time to examine the Packet Whacker and Frame Thrower packages, you'll see that both devices require the services of an external host microcontroller. Shortly after the introduction of the ENC28J60 Ethernet controller IC, Microchip melded the functionality of the ENC28J60 into a family of Ethernet-enabled PIC microcontrollers. The heart of our serial-to-Ethernet embedded hardware is the baby of that family: the 64-pin PIC18F67J60. The PIC18F67J60 was selected because it is a proven Ethernet platform. I also chose this PIC for historical reasons. If you take a stroll through the July/August 2007 issues of *Nuts & Volts*, you'll find a project that used the PIC18F67J60 as a target for porting the EDTP PIC18F67J60 C Ethernet drivers to PICBASIC PRO. Yet another reason for choosing this PIC18F67J60 for this project is its availability. You can obtain a PIC18F67J60-based EDTP Ethernet MINI development board right now from the EDTP website. In addition, everything you need to assemble and test your Ethernet MINI is available for a download from the links on the home page.

We'll use an Ethernet MINI like the one you see in **Photo 1** to test our Microchip Version 5.00 TCP/IP Stack configuration. Once we tune in its firmware, we'll replace the Ethernet MINI's onboard ST3232 RS-232 interface IC with a PIC18F14K50 low pin count USB device and do some USB Framework code tweaking.

Think of the Ethernet MINI as a hardware building block whose services we will combine with other firmware building blocks contained within the TCP/IP Stack and the USB Framework. Once you have your Ethernet MINI assembled and tested, you'll be ready to move on to the TCP/IP Stack configuration process we're about to discuss.

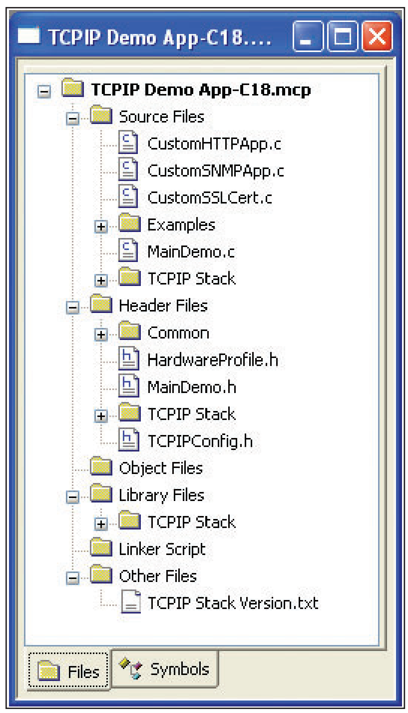
TWEAKING THE STACK

At a glance, the TCP/IP Stack seems to be a formidable piece of code. I'm here to tell you that it is. However, if you approach it from a modular point of view, it becomes a thing of beauty.

The Microchip coding crew was thoughtful enough to supply a number of precompiled examples and ready-to-compile MPLAB projects with the stack download package. So, let's begin our stack configuration with some blind experimentation. If you install the TCP/IP Stack using the defaults, it will put itself into the *C:\Microchip Solutions* directory. There's a C18 demo application we'll run first called *TCPIP Demo App-C18.mcp* that resides inside of the *TCPIP Demo App* directory, which is contained within the stack's *C:\Microchip Solutions* root directory. I currently have MPLAB 8.30 installed and a click on the *TCPIP Demo App-C18.mcp* directory entry brought the demo application's MPLAB workspace to life. The *MPLAB TCPIP Demo App-C18* project window you see in **Screenshot 1** is a good example of how we should package the TCP/IP Stack and our associated application files into an MPLAB project. Note that there are three *TCPIP Stack* folders in the MPLAB project window. The TCP/IP Stack source files — identified by a file name extension of *.c* — are stored in the *Source Files* project folder. All of the TCP/IP Stack header files — which have a file name extension of *.h* — are contained within the *Header Files* project folder. The TCP/IP Stack library files are located in the *Library Files* project folder and are topped off with a *.lib* extension. Applications, utilities, and any other executable source code modules are herded into the *Source Files* project folder.

All of the TCP/IP Stack examples are aimed at a specific PIC microcontroller family of devices or a Microchip demonstration board such as the Explorer 16. The EDTP Ethernet MINI is a bare bones design and has little in common with any of the official Microchip demo boards. However, the EDTP MINI's PIC18F67J60 implementation is strictly a by-the-book Microchip design. So, we have a very good chance of getting the *TCPIP Demo App-C18* project to run with the EDTP Ethernet MINI hardware out of the box.

Please allow me to update that last statement. We have no chance of getting the *TCPIP Demo App-C18* project to run with the EDTP Ethernet MINI hardware out of the box. I attempted to compile the *TCPIP Demo App-C18* project and received an EEPROM error that is associated with the MPFS (Microchip File System). Since the EDTP MINI hardware design doesn't include an external EEPROM, I decided to simply eliminate external EEPROM and MPFS support from the stack build. The *TCPConfig.h* file may hold the key to success as it contains the MPFS configuration switches. With that



■ SCREENSHOT 1. The TCP/IP Stack files are loaded into the trio of *TCPIP Stack* folders. The Microchip TCP/IP Stack source files all have a file name extension of *.c* and if a source file requires a companion header file, that file has an extension of *.h*. TCP/IP Stack library files for the C18 devices are appended with .lib file name extensions.

thought in mind, I accessed the *TCPConfig.h* file with the MPLAB editor and commented out the definition you see here:

```
/* MPFS Storage Location
 *   If html pages are stored in internal
 *   program memory, comment both MPFS_USE_
 *   EEPROM and MPFS_USE_SPI_FLASH, then
 *   include an MPFS image (.c or .s file) in
 *   the project. If html pages are stored in
 *   external memory, uncomment the appropriate
 *   definition.
 *
 *   Supported serial flash parts include the
 *   SST25VFxxxB series.
 */
//#define MPFS_USE_EEPROM   //Fred commented
                            //this line
//#define MPFS_USE_SPI_FLASH
```

After performing the comment-eliminate operation in the *TCPConfig.h* file, I again kicked off a project compile. This time, the stack components and all of the application files compiled with no problems. However, the C18 linker ran out of available PIC program memory and could not squeeze in the TCP/IP Stack's Telnet application module. This really doesn't constitute a compilation problem. We're just flat out of PIC18F67J60 program memory. So, let's go back to the *TCPConfig.h* file and do some additional trimming. We can remove stack features and cut our stack program memory usage by simply commenting the unneeded application modules out in the *TCPConfig.h* file. As you can see in the code snippet in the box below, I only eliminated application modules we're not interested in using for our serial-to-Ethernet application.

Note that I didn't eliminate the ability of our EDTP Ethernet MINI to use DHCP for automatic network addressing. I also retained the ICMP functionality, which allows the MINI to be PINGed. The TCP/IP Stack encapsulates demo programs that come in handy for operational testing. One such demo program is kicked off when the Telnet Server application is accessed. I've kept some of the application modules that are associated with a demo to give us a visual cue as to the operation of the stack and MINI hardware.

The additional pruning paid off. Our modified out-of-the-box TCP/IP Stack configuration compiled and linked with no errors. It's time to load the resultant TCP/IP Stack hex file into the PIC18F67J60 and count the heads when the smoke clears. My test network consists of a generic Linksys wireless router, a Lenovo S10 running the Wireshark Network Analyzer, the Microchip Announce Detector and Tera Term Pro, a Lenovo laptop, and the EDTP Ethernet MINI. The Lenovo laptops are wirelessly connected to the network leaving the MINI as the only host that is hard-wired to the Linksys router. I'll use the Lenovo to communicate with the MINI.

The programming session went off without a hitch. Within a few seconds, the new IP address assigned to the MINI was displayed in the Tera Term Pro window. This is a good sign as the stack's DHCP and ARP components have been verified with the appearance of the IP address message. I captured the DHCP process in **Shark Capture 1**.

The first thing that the TCP/IP Stack does is to attempt to contact another host that may have the same IP address. Hopefully, no other host will answer. Another reason for the *Gratuitous ARP* is to refresh any host ARP tables that may be out of date. According to the Wireshark capture, no other hosts responded to the recon ARP. So, the way is clear for the MINI to discard its default

```
/* Application Level Module Selection
 *   Uncomment or comment the following lines to enable or
 *   disabled the following high-level application modules.
 */
#define STACK_USE_UART                          // Application demo using UART
#define STACK_USE_UART2TCP_BRIDGE               // UART to TCP Bridge application example
//#define STACK_USE_IP_GLEANING
#define STACK_USE_ICMP_SERVER                   // Ping query and response capability
#define STACK_USE_ICMP_CLIENT           // Ping transmission capability
//#define STACK_USE_HTTP_SERVER                 // Old HTTP server
//#define STACK_USE_HTTP2_SERVER                // New HTTP server
//#define STACK_USE_SSL_SERVER                  // SSL server socket support
//#define STACK_USE_SSL_CLIENT                  // SSL client socket support (Requires SW300052)
#define STACK_USE_DHCP_CLIENT                   // Dynamic Host Configuration Protocol client
#define STACK_USE_DHCP_SERVER                   // Single host DHCP server
//#define STACK_USE_FTP_SERVER                  // File Transfer Protocol (old)
//#define STACK_USE_SMTP_CLIENT                 // Simple Mail Transfer Protocol for sending email
//#define STACK_USE_SNMP_SERVER                 // Simple Network Management Protocol v2C
//#define STACK_USE_TFTP_CLIENT                 // Trivial File Transfer Protocol client
//#define STACK_USE_GENERIC_TCP_CLIENT_EXAMPLE  // HTTP Client example in GenericTCPClient.c
//#define STACK_USE_GENERIC_TCP_SERVER_EXAMPLE  // ToUpper server
#define STACK_USE_TELNET_SERVER                 // Telnet server
#define STACK_USE_ANNOUNCE                      // Microchip Device Discoverer server/client
#define STACK_USE_DNS                   // Domain Name Service Client
#define STACK_USE_NBNS                          // NetBIOS Name Service Server
#define STACK_USE_REBOOT_SERVER                 // Module for resetting this PIC remotely
#define STACK_USE_SNTP_CLIENT           // Simple Network Time Protocol
//#define STACK_USE_UDP_PERFORMANCE_TEST        // Module for testing UDP TX performance
//#define STACK_USE_TCP_PERFORMANCE_TEST        // Module for testing TCP TX performance
#define STACK_USE_DYNAMICDNS_CLIENT     // Dynamic DNS client updater module
#define STACK_USE_BERKELEY_API                  // Berekely Sockets APIs are available
```

IP address which is set in the *TCPConfig.h* file and request a valid IP address from the Linksys router. Ultimately, the Linksys router makes an offer that the MINI's stack can't refuse and an IP address is leased to it.

Once the MINI has a valid IP address, it sends a UDP message on port 30303 courtesy of the TCP/IP Stack's ANNOUNCE application module. I captured the success message in the Microchip Announce Detector window in **Screenshot 2**. The IP address shown in Screenshot 2 is the new address assigned to the EDTP MINI. The NetBIOS name — MCHPBOARD — is what is currently hard-coded in the *TCPConfig.h* file. Microchip owns MAC addresses that begin with 00-04-43. The default MAC address you see in Screenshot 2 is also hard-coded within the *TCPConfig.h* file. The TCP/IP Stack's UDP engine is obviously working just fine.

Recall that we included the Telnet Server application module in our TCP/IP Stack configuration. To verify the Telnet Server running on the MINI, I used the Windows Telnet client application on the Lenovo laptop to log into the EDTP Ethernet MINI's Telnet Server engine. Take a look at **Screenshot 3**. The SNTP application module is another TCP/IP Stack feature we retained and you can see that it's being exercised with success in the Telnet application. The Analog entry in Screenshot 3 is bogus as the default TCP/IP Stack analog input pin does not have an analog input voltage applied to it. The same goes for the Buttons and LEDs readouts as the MINI has no buttons or banks of LEDs. Fret not. We can "fix" all of this.

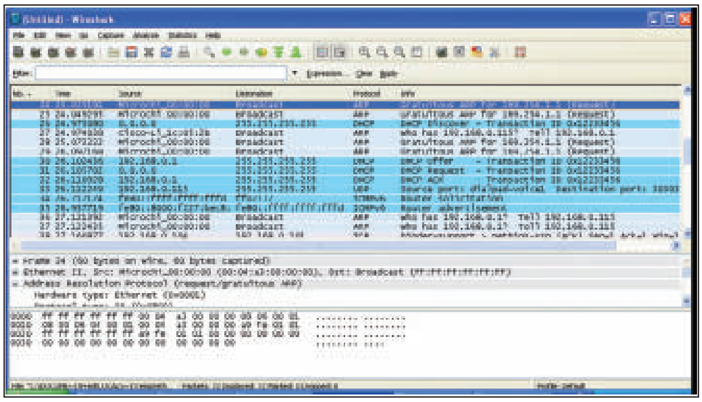
TWEAKING THE HARDWARE

The TCP/IP Stack is written to accommodate a variety of Microchip development boards. We can add our EDTP Ethernet MINI to the "official" list by doing some work on the stack's *HardwareProfile.h* file. The first step involves defining the MINI to the stack by replacing the YOUR_BOARD definition with ETHERNET_MINI. Here's the code snippet as it appears in the *Hardware Profile.h* file:

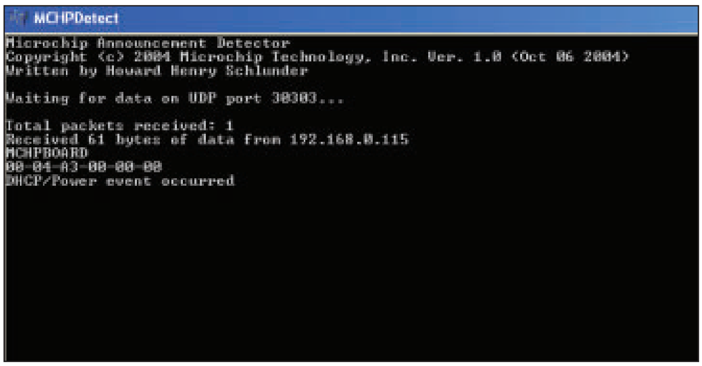
```
// Choose which hardware profile to compile for
// here.  See the hardware profiles below for
// meaning of various options.
//#define PICDEMNET2
//#define PIC18_EXPLORER
//#define HPC_EXPLORER
//#define PIC24FJ64GA004_PIM    // Explorer
                                // 16 with
                                // the PIC24FJ
                                // 64GA004 PIM
//#define EXPLORER_16// PIC24FJ128GA010,
PIC24HJ256GP610, dsPIC33FJ256GP710 PIMs
//#define DSPICDEM11
//#define YOUR_BOARD
```

This code snippet shows the change:

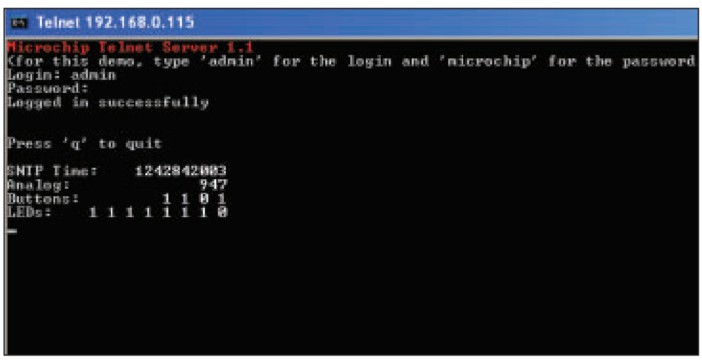
```
// Choose which hardware profile to compile for
// here. See the hardware profiles below for
// meaning of various options.
//#define PICDEMNET2
//#define PIC18_EXPLORER
//#define HPC_EXPLORER
//#define PIC24FJ64GA004_PIM   // Explorer 16
                               // with the
```



■ SHARK CAPTURE 1. If you need more detailed information about the contents of a Wireshark capture, you can consult the Wireshark Wiki (http://wiki.wireshark.org). This Wireshark capture contains the DHCP steps taken by the Microchip TCP/IP Stack and the Linksys router's DHCP server function to assign a valid IP address to the EDTP Ethernet MINI.



■ SCREENSHOT 2. This shot reveals the EDTP Ethernet MINI's newly assigned IP address, its NetBIOS name (MCHPBOARD), and the default Microchip MAC address. If you take time to read the TCP/IP Stack's header files, you'll find that Mr. Schlunder is a MAJOR contributor to the code that makes up the Microchip TCP/IP Stack. Good job, Howard!



■ SCREENSHOT 3. The content of this capture assumes that the Microchip TCP/IP Stack code is running against a known Microchip development board. For instance, the application sees the button in the binary 2 position as depressed and the LED in the zero position extinguished.

```
                              // PIC24FJ
                              // 64GA004 PIM
//#define EXPLORER_16// PIC24FJ128GA010,
PIC24HJ256GP610, dsPIC33FJ256GP710 PIMs
//#define DSPICDEM11
#define ETHERNET_MINI
```

By defining the hardware as an EDTP Ethernet MINI development board, we have set a filter value that will be used to select configuration options as we tumble down through the *HardwareProfile.h* file's code. The PIC microcontroller that we select from the MPLAB *Configure* drop-down menu also has a say in the stack configuration process. The next step involves setting the PIC18F67J60's configuration fuses. This is the path that will be taken based on the MPLAB device selection and the compiler that MPLAB has been instructed to use:

```
// Set configuration fuses (but only once)
#if defined(THIS_IS_STACK_APPLICATION)
~~~~ //cut to the chase
#elif (defined(__18F97J60) ||
defined(__18F96J65) || defined(__18F96J60) ||
defined(__18F87J60) || defined(__18F86J65) ||
defined(__18F86J60) || defined(__18F67J60) ||
defined(__18F66J65) || defined(__18F66J60)) &&
!defined(HI_TECH_C)
// PICDEM.net 2 or any other PIC18F97J60
// family device
#pragma config WDT=OFF, FOSC2=ON, FOSC=HSPLL,
ETHLED=ON
```

I cut to the chase in the configuration fuse code snippet as there are many PIC microcontroller configuration branches traversed before landing on the correct PIC18F67J60 limb. As you can see in the code snippet, the HI-TECH PICC-18 compiler is not a positive choice for this configuration.

The next block of code we tumble through selects a clock frequency value. Since we've defined a unique piece of hardware, we must do a bit of freelance coding to get the right value for our PIC18F67J60. If you were to check the original code, you would find that I have manually added our ETHERNET_MINI definition to the code snippet's conditional *#if* statement:

```
// Clock frequency value.
// This value is used to calculate Tick
// Counter value
#if defined(__18CXX)
       // All PIC18 processors
       #if defined(PICDEMNET2) || defined
       (INTERNET_RADIO || defined(ETHERNET_MINI)
              #define GetSystemClock()
                 (41666667ul)       // Hz
              #define GetInstructionClock()
                 (GetSystemClock()/4)
              #define GetPeripheralClock()
                 GetInstructionClock()
```

The MINI configuration is most like that of the PICDEM.net 2 development board as the PICDEM.net 2 is powered by a PIC18F97J60. The only major difference in the PIC18F67J60 and its big brother is the number of available I/O pins. Thus, the PIC18F67J60's System Clock frequency is identical to the PIC18F97J60's.

Following the initialization procedures, the TCP/IP Stack spins in an endless cooperative multitasking loop. One of the tasks includes toggling LED0. Other tasks in the loop check the buttons and cycle the analog-to-digital converter. At this moment, none of the simple tasks I've listed are working as designed. So, let's activate LED0, the buttons, and the analog-to-digital converter by adding some I/O definition code to our custom *HardwareProfile.h* file. By coincidence, the next level we tumble through defines the hardware to the stack. In our case, that piece of code didn't exist until it was manually added.:

```
#elif defined(ETHERNET_MINI)
// Define your own board hardware profile here
       // I/O pins
       #define LED0_TRIS    (TRISFbits.TRISF1)
       #define LED0_IO      (LATFbits.LATF1)
       #define LED1_TRIS    (PRODL)   // No LED1
                                      // on this
                                      // board
       #define LED1_IO      (PRODL)
       #define LED2_TRIS    (PRODL)   // No LED2
                                      // on this
                                      // board
       #define LED2_IO      (PRODL)
       #define LED3_TRIS    (PRODL)   // No LED3
                                      // on this
                                      // board
       #define LED3_IO      (PRODL)
       #define LED4_TRIS    (PRODL)   // No LED4
                                      // on this
                                      // board
       #define LED4_IO      (PRODL)
       #define LED5_TRIS    (PRODL)   // No LED5
                                      // on this
                                      // board
       #define LED5_IO      (PRODL)
       #define LED6_TRIS    (PRODL)   // No LED6
                                      // on this
                                      // board
       #define LED6_IO      (PRODL)
       #define LED7_TRIS    (PRODL)   // No LED7
                                      // on this
                                      // board
       #define LED7_IO      (PRODL)
       #define LED_GET()    (LED0_IO)
       #define LED_PUT(a)   (LED0_IO = (a))

       #define BUTTON0_TRIS (TRISBbits.TRISB3)
       #define BUTTON0_IO         (PORTBbits.RB3)
       #define BUTTON1_TRIS (TRISBbits.TRISB2)
       #define BUTTON1_IO         (PORTBbits.RB2)
       #define BUTTON2_TRIS (TRISBbits.TRISB1)
       #define BUTTON2_IO         (PORTBbits.RB1)
       #define BUTTON3_TRIS (TRISBbits.TRISB0)
       #define BUTTON3_IO         (PORTBbits.RB0)
```

SOURCES

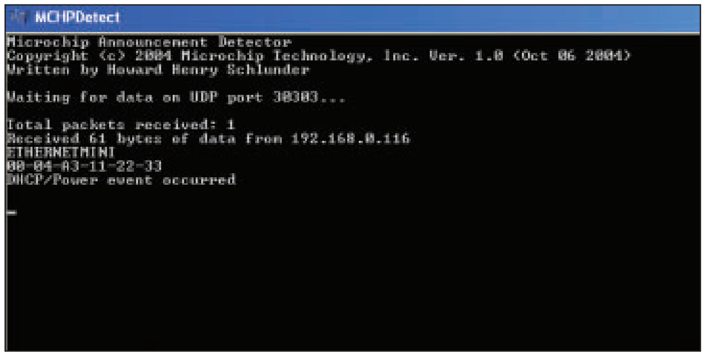
Wireshark Wiki — www.wireshark.org
Wireshark Network Analyzer

EDTP Electronics, Inc. — www.edtp.com
EDTP Ethernet MINI

Microchip — www.microchip.com
PIC18F67J60
PIC18F14K50
MPLAB REAL ICE
MPLAB
Microchip C18 C Compiler
Microchip TCP/IP Stack Version 5.00

As you can see in the hardware profile code snippet, we associated LED0 with I/O pin RF1, which matches up with the MINI hardware design. The BUTTONx pin assignments are legal as per the MINI schematic; these PORTB pins are available. The active analog-to-digital converter input is defined as RA0 in the *MainDemo.c* application file and that I/O pin is also available in the MINI design.

The final limb we must fall from to firm up our MINI hardware profile is to select the correct UART for the stack's UART2TCP_BRIDGE application module. The 16- and 32-bit PICs support a pair of UART. The stack assumes the use of UART2. So, it's just a matter of replacing every 2 with a 1 in the code just as I've done in the box below.



■ SCREENSHOT 4. The Microchip TCP/IP Stack may seem very complicated. However, if you follow its logic, the stack will do everything in its power to help you realize a successful implementation of your embedded network.

WATCH THIS!

I did some more tweaking before pulling the trigger on **Screenshot 4**. Note that I modified the MAC address and changed the NetBIOS name to something more appropriate. The MINI's LED0 is now blinking when the stack is running and I tested the Buttonx inputs and the analog-to-digital converter input by grounding them and observing the changes in the Telnet Server application.

There is still some fat that we can trim from the TCP/IP Stack. However, right now that's not important. We'll fine-tune the stack after we install the USB front end. In the meantime, I've supplied the modified versions of the *TCPConfig.h* and *HardwareProfile.h* files in the download package available on the *Nuts & Volts* website at **www.nutsvolts.com**. Next time, we'll work on configuring and installing the PIC18F14K50 front end. And, by the way ... you can add the Microchip TCP/IP Stack to your Design Cycle. **NV**

```
// Select which UART the STACK_USE_UART and STACK_USE_UART2TCP_BRIDGE
// options will use.  You can change these to U1BRG, U1MODE, etc. if you
// want to use the UART1 module instead of UART2.
#define UBRG                      U1BRG
#define UMODE                     U1MODE
#define USTA                      U1STA
#define BusyUART()                BusyUART1()
#define CloseUART()               CloseUART1()
#define ConfigIntUART(a)    ConfigIntUART1(a)
#define DataRdyUART()                    DataRdyUART1()
#define OpenUART(a,b,c)     OpenUART1(a,b,c)
#define ReadUART()                ReadUART1()
#define WriteUART(a)              WriteUART1(a)
#define getsUART(a,b,c)                  getsUART1(a,b,c)
#if defined(__C32__)
      #define putsUART(a)                putsUART1(a)
#else
#define putsUART(a)               putsUART1((unsigned int*)a)
#endif
#define getcUART()                getcUART1()
#define putcUART(a)  do{while(BusyUART()); WriteUART(a); while(BusyUART()); }while(0)
#define putrsUART(a)              putrsUART1(a)
```

More ALP Projects

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Joe's book & kits are available in our webstore at **www.nutsvolts.com**

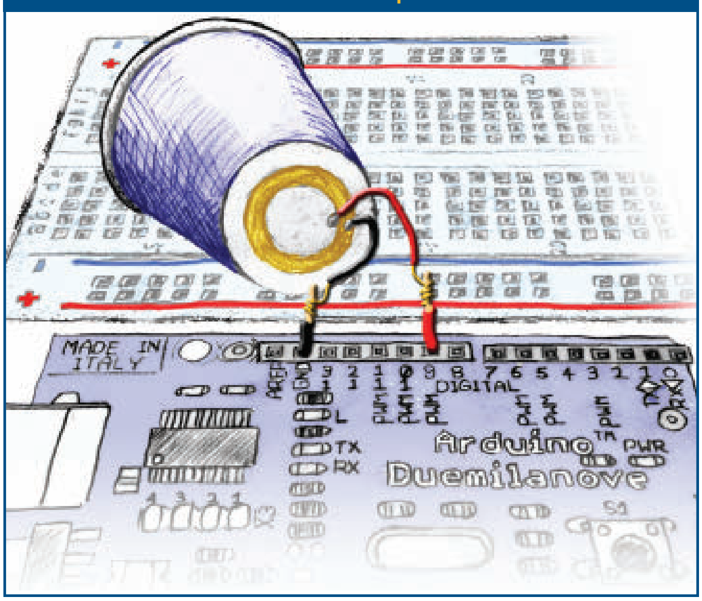
by Joe Pardue

Recap

In Workshop 9, we began using a new development board — the Arduino Duemilanove — recognizing that The Arduino Way (TAW) is a very simple and easy way to begin using microcontrollers. We learned, that while TAW uses a C-like language and has an easy to use IDE, it does not IMHO (In My Humble Opinion) provide a clear path to learning the C programming language or the details of the AVR architecture — both of which are our long-term goals for this Workshop series.

To help overcome this, we learned how to convert TAW code to work with the more standard Atmel AVR tools: AVRStudio, WinAVR, and AVRDude using A C Way (ACW). And, we put together the AVR Learning Platform (ALP) that uses the Smiley Micros Arduino Projects Kit (available from *Nuts & Volts*; **www.nuts&volts.com** and Smiley Micros; **www.smileymicros.com.**). This will provide our hardware development system for many Workshops to come.

■ FIGURE 1. ALP with piezo element.



For the next few workshops, we will show the code in (TAW) and leave (ACW) in the associated workshop zip files. After we finish with this introduction to using the kit parts, we will continue the series using ACW since we will want to do things that cannot be easily done TAW (such as using timer interrupts). So, if you are feeling a little confused, that's a good thing. It means you've been paying attention.

Last month, we did another communications project, learned to read the voltage across a potentiometer, and then revisited some Cylon Optometry. This month, we are going to develop a command interpreter, and then make some noise.

ALP Number Command Interpreter

In WS12, we learned how to send data from a PC terminal to the ALP to set the brightness of an LED. Let's expand on that to allow us to send number commands to the ALP and then use those commands to select different functions in our software, specifically, we will use this in a little while to select some tunes. In a later Workshop, we will expand on this so that we can send words not just numbers, and pretend that we are having a natural language conversation with our AVR. We won't be, but it can get downright spooky how well these things can pretend to be talking to you.

This code is shown here in TAW. The ACW code is in the Workshop13.zip download on the *Nuts & Volts* website.

We will be using the function cmdParse to decide what other functions to call, depending on the user input of a number. The user opens a terminal program, such as the Serial Monitor in the Arduino IDE (**Figure 3**), and sends a number from 0 to 4 to call one of the cmd#() functions (where # is 0 to 4). Sending any other number will cause the program to send an error message. In this

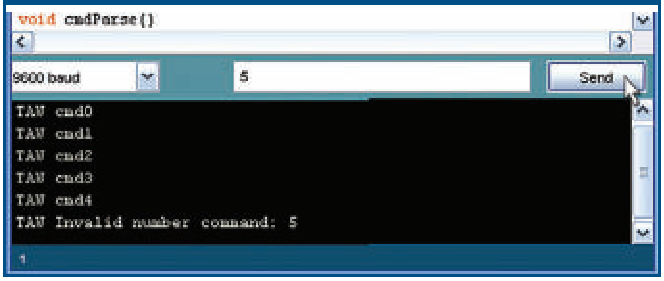
example code, each command function simply sends back a string noting that the command has been received.

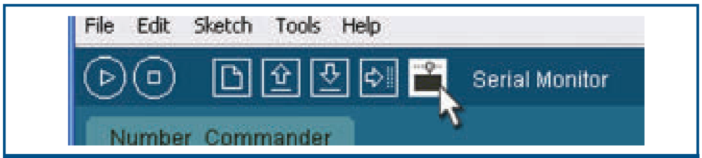
[It will probably help if you refer to the source code cmdParse() function in the Number_Commander while reading this paragraph.] Our command parser uses a C programming language switch statement that takes the command number as a parameter and then looks through a list of case statements to find the case corresponding to the command number. For each case, there is a list of things to do if that particular case is the correct one. We use this to call a function associated with the particular command and when the function returns, we call 'break' so that the code exits the switch statement (no need to look further down the list since we have already run the case it was looking for). If the switch statement gets to the bottom of the case list and still hasn't found the correct case, then a 'default' case is run which, in our case, tells the user that a bad command was sent and shows the invalid number.

In C, there are two main methods for deciding among a list of possibilities: the switch/case or the if/else constructions. Some folks want to know why C needs both or how to decide when to use which one. If you want to start an argument, bring this up on any C related forum, but my rule of thumb is that if you have fewer than four choices, the if/else will probably be best. If you have four or more, then the switch will probably be best, but the only real way to decide this is to do both and then look at the compiler output and see how it handled it. Different C compilers might handle the same code differently. For our purposes, either way would suffice since we aren't code size or speed constrained, but I tend to use the switch statement because it just looks better to me.

```
// Number_Commander TAW
// Joe Pardue May 11, 2009

int cmd = 0;

void setup()
{
  Serial.begin(9600);
}

void loop()
```

■ FIGURE 3. Number commander in the serial monitor.

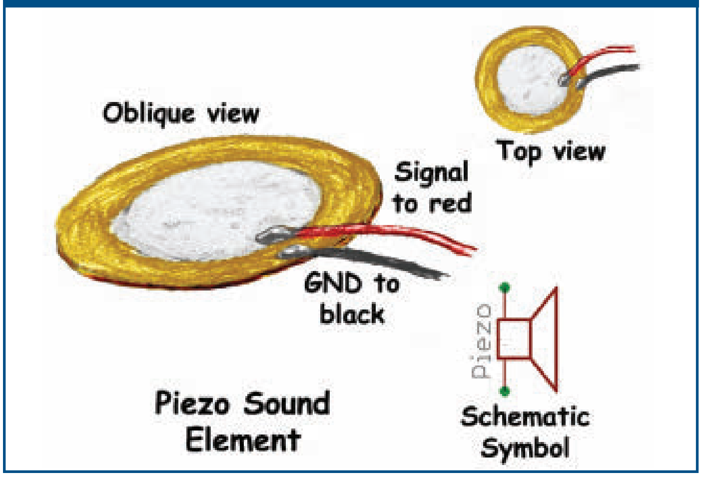


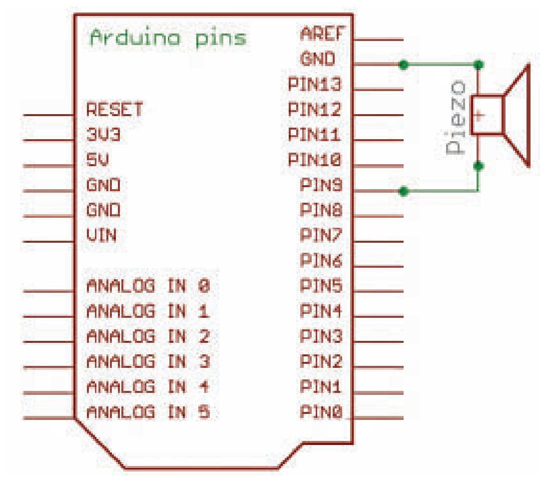


■ FIGURE 2. Select the Arduino IDE serial monitor.

```
{
  // check if data has been sent from the
  // computer
  if (Serial.available()) {
    cmdParse();
  }
}

void cmdParse()
{
  cmd = Serial.read();

  switch(cmd)
  {
    case ‘0’:
      cmd0();
      break;
    case ‘1’:
      cmd1();
      break;
    case ‘2’:
      cmd2();
      break;
    case ‘3’:
      cmd3();
      break;
    case ‘4’:
      cmd4();
      break;
    default:
      Serial.print(“TAW Invalid number command:
“);
      Serial.println(cmd, BYTE);
```

■ FIGURE 4. Piezo sound element.





■ FIGURE 5. Arduino with piezo element schematic.

```
break;
  }
}

void cmd0()
{
  Serial.println("TAW cmd0");
}

void cmd1()
{
  Serial.println("TAW cmd1");
}

void cmd2()
{
  Serial.println("TAW cmd2");
}

void cmd3()
{
  Serial.println("TAW cmd3");
}

void cmd4()
{
  Serial.println("TAW cmd4");
}
```

A few folks have informed me that my Developer's Terminal is printing in Chinese under some circumstances that I can't duplicate (at first, I though 'Chinese' was just a way of them saying it was random characters, but no, in fact it was Chinese), so check my website to see if this is fixed yet. If not, use either my Simple Terminal or Bray's Terminal or, as we will do for this example, use the Serial Monitor (as shown in **Figures 2** and **3**) that comes with the Arduino IDE.

* note	frequency	period	timeHigh
* c	261 Hz	3830	1915
* d	294 Hz	3400	1700
* e	329 Hz	3038	1519
* f	349 Hz	2864	1432
* g	392 Hz	2550	1275
* a	440 Hz	2272	1136
* b	493 Hz	2028	1014
* C	523 Hz	1912	956

■ FIGURE 6. Note table.

Making Sounds with a Piezo Element

We are advised to make a joyful noise, and what better way than with a piezo element? Well, honestly, just about anything would be better — you don't get much more low fidelity than this. Even calling the sound it makes 'noise' is being generous — so, let's ask 'What's cheaper?' We are now getting somewhere since these things are cheap and don't require any external amplification circuitry.

We will listen to high pitched, squeaky renditions of 'Twinkle Twinkle Little Star,' 'Happy Birthday to You', and a couple of alarms. [WARNING: Only listen to a tune once or twice, or it will get stuck in your head forcing you to listen to an hour of Johnny Rotten just to get it out!]

The piezo element in the Arduino Projects Kit is made from a brass disc with a ceramic disc adhered to it. The brass has the negative (black) wire and the ceramic has the positive (red) wire soldered to it. These wires are stranded and can't be used directly with a breadboard, so take two pieces of 22 AWG solid wire and solder them as extensions to the piezo wires. (See **Figure 1.)**

The piezo element warps in response to voltage changes and if this warping is at audible frequencies, you can hear it. I glued (Elmer's©) the brass side of the piezo to the outside base of a Dixie© cup (one of those small cups you sometimes see in bathroom dispensers). You may be able to hear the sound without the cup, but the cup provides a resonant cavity (or some such techno-buzz words) that mechanically amplifies and directs the sound.

BTW, there are many piezo buzzers out there and they often have special circuitry to create their own buzz, meaning they are either quiet or squalling, but can't be made to output a specific frequency and are not suitable for this project.

Sound Components, Schematic, and Layout

The piezo element drawing and schematic symbol from the Arduino Projects Kit are shown in **Figure 4**; the schematic for the project is in **Figure 5**; and the layout illustration is in Figure 1.

Tunes

The musical part of the code is based on the Arduino IDE example Melody code written by D. Cuartielles that I expanded to include another tune and some interesting

noises. For us to create a recognizable tune, we need to control the musical notes (tones) and the duration between the notes (beat). For simple tunes, we can live with eight tones (a music octave) each having a specific frequency. Each of these tones has a letter 'note' assigned to it by musicians as in **Figure 6**.

We will keep this as simple as possible and generate these notes using the Arduino library delayMicroseconds function. (A microsecond is 1/1,000,000 second — yes: one millionth of a second — you have heard that computers are fast, haven't you?)

To generate the 'c' note, we create an output waveform (see **Figure 7**) that turns on and off with a frequency of 261 cycles per second. Each of these on/off cycles occurs in 1/261 of a second or 0.003831 seconds. Since we are dealing with microseconds, we multiply this by 1,000,000 to get 3,831 microseconds per cycle. Since we need to cycle the pin (turn the pin on and off) in that time, we turn it on for 3831/2 = 1,915 microseconds (throwing away the fractional part) and off for 1,915 microseconds giving us a total of 3,830. We lost 1 due to our not wanting to use fractions, but who is going to miss a microsecond?

In the Tunes program, we use a playTone function that takes the tone and the duration as parameters. A loop repeats the on/off cycle for the note parameter for a length of time in the duration parameter. It might, for instance, turn the speaker on for 1,915 uS and off for 1,915 uS repeating for a full second to give a rather long 'c' note. The playTone function is called by the playNote function that has the job of reading through the tune array to get the next note/duration combination.

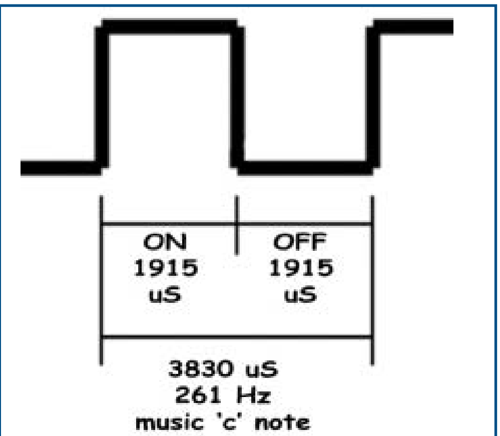
Each tune is played by an individual function that contains two arrays: one for the tune notes and one for the tune beat. It calculates the duration from the beats and sends that duration along with the tune note to the playNote function. The playNote function reads through an array of note names and uses that name position in that array to get the number for the microseconds needed to play that note. It then calls playTone with the tone microseconds and the duration as parameters.

The playTone uses those parameters to turn the pin connected to the piezo element on and off, thus generating exquisite music like none heard since the last pterodactyl blundered into a fern tree.

Tunes Source Code

The Tunes source code is shown here in TAW abridged from the full code that is available along with the ACW version in Workshop13.zip. It is shortened since there is a lot of repetition in how the tunes are played. Twinkle, Twerdle, Euro Siren, and Beep Beep are in the zip file. AND a note to more experienced programmers: Yes, I know this isn't the 'best' way to do this, but this is instructional code for novices. I have some comments with the zipped code about better ways and I will show those ways in a future workshop.

```
/* TAW Tunes
 * Joe Pardue May 13, 2009
 * based on Arduino example code Melody
 * www.arduino.cc/en/Tutorial/Melody
 * (cleft) 2005 D. Cuartielles for K3
 */

// define numbers for tunes
#define Twinkle 0
#define Happy_Birthday 1
#define Euro_Siren 2
#define Twerdle 3
#define Beep_Beep 4

// create and intialize global variables
int speakerPin = 9; // pin to drive the piezo
element
int tune = 0; // tune to play

void setup() {
  Serial.begin(9600);
  pinMode(speakerPin, OUTPUT);

  // greetings
  Serial.println("TAW Tunes");
  Serial.println("Enter 0 for Twinkle Twinkle
Little Star");
  Serial.println("Enter 1 for Happy Birthday");
  Serial.println("Enter 2 for Euro Siren");
  Serial.println("Enter 3 for Twerdle Alarm");
  Serial.println("Enter 4 for Beep Alarm");
}

void loop() {
  // check if data has been sent from the
  // computer
  if (Serial.available()) {
       cmdParse(); // if true, get the data and
parse it
  }
```



■ FIGURE 7. 'C' note waveform.

```
}

// use a switch statement to decide which tune
// to play
void cmdParse(){

tune = Serial.read();

  switch(tune){
    case ‘0’:
      play_Twinkle();
      break;
    case ‘1’:
      play_Happy();
      break;
    case ‘2’:
      play_Euro();
      break;
    case ‘3’:
      play_Twerdle();
      break;
    case ‘4’:
      play_Beep();
      break;
    default:
      Serial.print(“TAW Invalid tune: “);
      Serial.println(tune, BYTE);
      break;
  }
}

void playTone(int tone, int duration) {
  for (long i = 0; i < duration * 1000L; i +=
tone * 2) {
    digitalWrite(speakerPin, HIGH);
    delayMicroseconds(tone);
    digitalWrite(speakerPin, LOW);
    delayMicroseconds(tone);
  }
}

void playNote(char note, int duration) {
  char names[] = { ‘c’, ‘d’, ‘e’, ‘f’, ‘g’, ‘a’,
‘b’, ‘C’ };
  int tones[] = { 1915, 1700, 1519, 1432, 1275,
1136, 1014, 956 };

  // play the tone corresponding to the note
  // name
  for (int i = 0; i < 8; i++) {
    if (names[i] == note) {
      playTone(tones[i], duration);
    }
  }
}

//Happy Birthday
int Happy_length = 26; // the number of notes
char Happy_notes[] = “ccdcfeccdcgfccCafedbbafgf
“; // a space represents a rest
int Happy_beats[] = { 1, 1, 2, 2, 2, 4, 1, 1, 2,
2, 2, 4, 1, 1, 2, 2, 2, 2, 6, 1, 1, 2, 2, 2, 2,
4 };
int Happy_tempo = 150;
void play_Happy(){
  for (int i = 0; i < Happy_length; i++) {
    if (Happy_notes[i] == ‘ ‘) {
      delay(Happy_beats[i] * Happy_tempo);
       // rest
    } else {
      playNote(Happy_notes[i], Happy_beats[i] *
Happy_tempo);
    }

    // pause between notes
    delay(Happy_tempo / 2);
  }
}
```

Well, that’s all the room for this month. Next month, we will look at the Arduino Projects Kit light and temperature sensors along with some coding techniques for presenting fractional values of data without having to store fractions. **NV**

You can find the source code and supplements for this article in Workshop13.zip on the *Nuts & Volts* and Smiley Micros websites.

The Arduino Projects Kit

Smiley Micros and *Nuts & Volts* are selling a special ***Arduino Projects Kit***.

Beginning with Workshop 9, we started learning simple ways to use these components, and in later Workshops we’ll use them to drill down into the deeper concepts of C programming, AVR microcontroller architecture, and embedded systems principles.

With the components in this kit you can:

- *Blink eight LEDs (Cylon Eyes)*
- *Read a pushbutton and eight-bit DIP switch*
- *Sense voltage, light, and temperature*
- *Make music on a piezo element*
- *Detect objects and edges*
- *Optically isolate voltages*
- *Fade LED with PWM*
- *Control motor speed*
- *And more ...*

A final note: The USB serial port on the Arduino uses the FTDI FT232R chip that was discussed in detail in the article “The Serial Port is Dead, Long Live the Serial Port” *by yours truly*, in the June 2008 issue of *Nuts & Volts*. You can also get the book “Virtual Serial Programming Cookbook” *(also by yours truly)* and associated projects kit from either *Nuts & Volts* or Smiley Micros.

BY LOUIS E. FRENZEL W5LEF

HOW TO ACHIEVE 1 GIGABIT PER SECOND DATA RATE OVER WIRELESS

Not as easy as you think, but it is being done

In the wireless field, we talk a great deal about high speed data. For example, with Wi-Fi connections on our laptops we usually get at least 20 million bits per second (Mbps) through a typical hot spot, home router, or access point, but rarely the 54 Mbps maximum possible. Longer distances, interference, and other environmental issues usually prevent that, but what we get is typically enough. With the new 802.11n standard, Wi-Fi speeds will be going up as more of the access points adopt the multiple input multiple output (MIMO) technology that will make 100+ Mbps common.

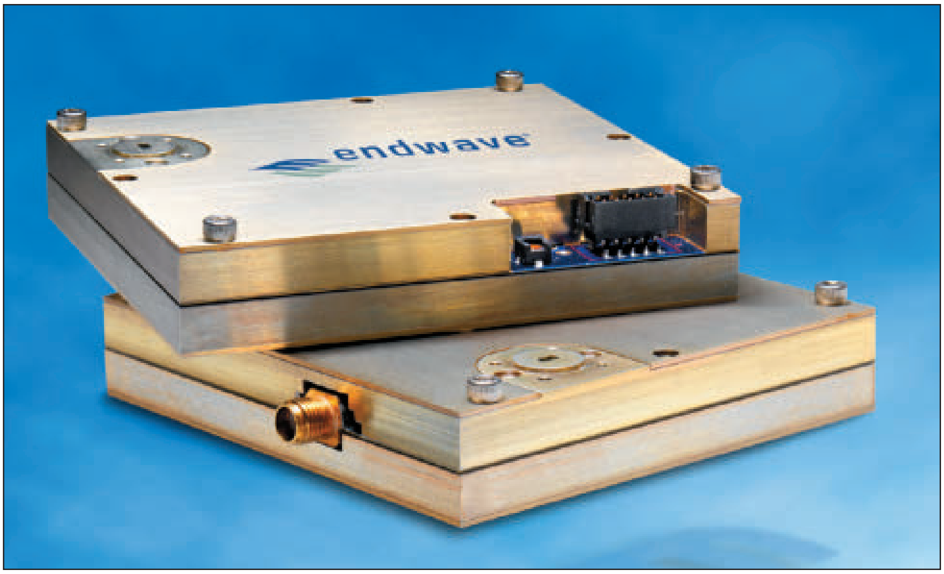
The 3G data connections in laptops and cell phones are not that fast, but do give most of us at least 1 or 2 Mbps. It's fine for email and Internet browsing. If you have one of the more advanced cell phone connections with Rev. A or Rev. B cdma2000 or HSDPA (high speed downlink packet access), you can get even faster rates of upwards of 5 to 14 Mbps. Not bad.

The question is, how do you get more speed if you need it? Or, maybe the better question is why do you need that speed over a wireless connection, anyway? The primary answer is that there are cases when one enterprise data center or office needs maximum speed over a short distance between two locations where running a cable is not an option. A wireless link is the preferred method or the only method. To get gigabit data rates over a radio link, the operating frequency needs to be higher than the data rate by a factor of at least five or ten. That means radios that operate well into the gigahertz range (GHz) or even the millimeter (mm) wave range. Remember that mm waves are those radio signals in the 30 to 300 GHz range. While you do not hear much about such wireless systems, they are out there. **Figure 1** shows one made by Endwave. The transmitter and receiver operate in the 71 to 86 GHz range. This is the so-called microwave E-band. (Now that's high frequency!) Data rates can be multi-gigabit per second. While the maximum range is only a few miles over a direct line of sight (LOS) path, this radio is way cheaper than a fiber link — the only wired connection that can handle the speed.

There is one other high speed wireless need and that revolves around transmitting uncompressed video between consumer electronics (CE) boxes in the home without cables.

CONSUMER ELECTRONICS SYSTEMS DEMAND HIGH SPEED

With HDTV becoming the norm in video, we want to preserve all the resolution there is in the video to get the best possible picture. Since moving HD digital video requires a serial data speed of about 1.5 Gbps, you need to use special cables capable of handling that rate between the TV set and the cable box, or between the TV set and the DVD/Blu-ray player. Optical and HDMI (high definition media interface) cables do this well in CE systems. With the goal of eliminating or at least minimizing the cable "rat's nest" common in CE systems, that



■ FIGURE 1. Endwave's point-to-point radios operate in the E-band from 71 to 86 GHz, the high mm wave area. They can deliver multi-gigabit data rates reliably in high speed networks for business and campuses, virtual private networks (VPNs), cellular and WiMAX backhaul, and a replacement for some fiber applications.

means some kind of wireless connection. If you want to do it wirelessly, it is a challenge.

There are a number of wireless solutions that can transmit compressed video at reasonable resolutions and speeds. Compressed video takes the raw digital video information and processes it to reduce the amount of data involved so as to reduce the transmission data rate. It works great but the compression causes loss of picture resolution so you don't get all the fabulous detail that the $3,000 1080p set you bought can give you.

Existing wireless technologies like Wi-Fi (802.11n with MIMO) and ultra wideband (UWB) offer compressed data transmission solutions with data rates of several hundred Mbps being common. If you don't mind a bit of resolution loss, these are available and affordable. Some say you can't really tell that detail is lost but others say you can.

If you really want to get all the resolution out of the HDTV set you paid for AND you want wireless flexibility, the choices have been limited up to now.

ACHIEVING HIGH DATA RATES OVER RADIO

We regularly get 1 Gbps and even 10 Gbps data rates over wired connections with twisted pair and fiber cables using Ethernet or Sonet/SDH optical protocols and network connections. You would think that getting 1 Gbps over wireless would be easy, but it's not. There are a minimal number of systems that do it and these are special military or government links, or expensive links used by large companies. The Endwave products shown earlier are a good example.

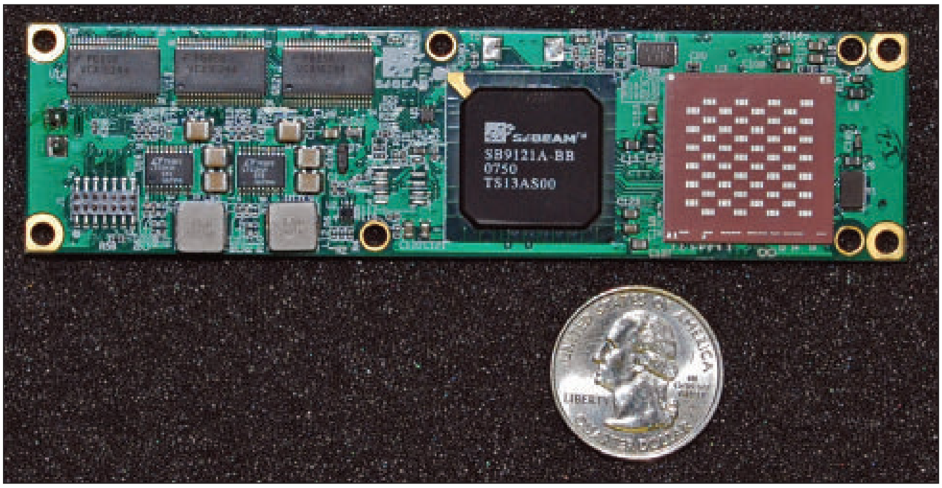
The problem stems from a mix of limited bandwidth to achieve the necessary data rate, the modulation methods, and the issues with noise and multipath signal transmissions caused by reflections. Overall, it is tough to do, especially at an affordable cost. A couple of companies have provided some chips that make this more practical. There are now some clever ways to get data rates exceeding 1 Gbps needed wirelessly for uncompressed video.

The most direct way is simply to increase the bandwidth available to transmit the signal. That is not always possible, however. Frequency spectrum is scarce and also regulated. For a given type of wireless like Wi-Fi, the standard states a spectrum of 20 MHz or 40 MHz under some conditions. Mostly, we do not have the bandwidth sufficient to transmit 1 Gbps or more directly. Generally, you need to move higher in the frequency spectrum to get more bandwidth higher frequency equipment is more difficult to make and so costs more.

Another way to get more speed is to use an advanced modulation method. Today, quadrature amplitude modulation (QAM) is the preferred method. It uses a combination of both amplitude and phase modulation to transmit data at rates 2, 4, 8, 16, 64, 128, or 256 times more than the base modulation method like binary phase shift keying (BPSK) in the same bandwidth.

Another modulation method that gets you up to higher speeds is orthogonal frequency division multiplexing (OFDM). In this technique, the high speed data stream is divided into hundreds or even thousands of slower data streams and all are transmitted simultaneously on separate subcarriers in a wide chunk of spectrum. The whole process is done mathematically in a digital signal processing (DSP) chip. Each subcarrier is usually modulated with some level of QAM. The result is very high speed in minimal spectrum. That is called spectral efficiency.

A third method is to use MIMO (multiple input multiple output) — a technique that employs multiple transmitters, receivers, and antennas. The high speed signal to be transmitted is divided up into two or more slower streams and these are transmitted simultaneously over several transmitters with separate antennas on the same frequency with the same bandwidth. These signals are then received by multiple receivers and antennas. For instance, using two transmitters and two receivers makes a 2x2 MIMO system. Because of the different paths that each signal takes, it is possible to sort out all the signals, recover them, and put them back together as the



■ FIGURE 2. This is the SiBEAM WirelessHD module operating at 60 GHz. Note the phased array antenna on the right. The main beam uses 36 elements and the other 16 are for return path communications and spares.

original fast data stream. With MIMO, you can really get very high speeds in limited bandwidth.

At one time, the cost of multiple transmitters, receivers, and antennas was prohibitive. Today, the IC companies put these all on one low cost chip. For example, one vendor puts 4 x 4 MIMO on a single 802.11n Wi-Fi chip that can achieve a data rate of 600 Mbps in a 20 MHz channel. That is excellent. The technique can extend that speed to beyond 1 Gbps.

This is the technique used by chip maker Amimon. The Amimon chips operate in the unlicensed spectrum around 5.8 GHz. That is the same band used by 802.11a Wi-Fi. They combine OFDM and a 4 x 5 MIMO (four transmitters and five receivers and antennas) to achieve a data rate as high as 3 Gbps in a 40 MHz channel — more than enough for uncompressed HD video. This technique is now a video transmission standard called Wireless Home Digital Interface (WHDI). You can find out more about it at **www.whdi.org** or **www.amimon.com**. WHDI is already being built into TV sets, set top boxes, and other devices line PCs, dongles, and video games. Look for more in the future as your home entertainment system connections go wireless.

Another wireless technology has emerged to also address the uncompressed video transmission problem. It too has become a standard called WirelessHD. Check out **www.wirelesshd.org** for more details. The first chips were made by SiBEAM. This technology uses the unlicensed mm wave band around 60 GHz. With a bandwidth of 7 GHz to play with, it is relatively easy to get data rates to well into the gigabit region. The standard calls for the use of OFDM and a wide bandwidth to get data rates to 4 Gbps. Uncompressed video is a snap. But, there are issues.

First, the range of a 60 GHz signal is usually short. In this application, the range is about 10 meters or a little over 30 feet. That is typical for video links at home. The big aggravation at mm wave frequencies is the reflections that cause multipath signals that can interfere with one another and cause fading. Multipath is the bane of microwave and mm waves. Furthermore, mm wave signals do not pass through objects very well like lower frequencies do. So, if your dog should walk between the transmitter and receiver you will momentarily block the signal. Millimeter waves are more like light waves that are easily blocked as with your TV infrared (IR) remote control.

SiBEAM has solved this problem by integrating a phased array antenna on the chip to implement very narrow beams of signal and automatic beam pointing to alleviate the multipath problem. At 60 GHz, your typical dipole antenna is only about 1/16th of an inch long so it is easy to place several make many on a single chip. What they did is put a 36 antenna array that automatically adjusts its directionality to maintain a radio link under multipath reflections or beam interruptions. A side benefit of the phased array is that it is a real power multiplier.

Focusing a radio wave beam with an antenna gives the same effect as raising transmitter power. We call that effective radiated power (ERP). A 100 mW signal can be made to act like a one watt or 10 watt signal giving greater transmission range and reliability.

Another effort to achieve above 1 Gbps data rates over wireless is that of the WiGig Alliance, an organization devoted to achieving a worldwide standard for high speed wireless data in the 60 GHz band. The IEEE's continuing efforts with Wi-Fi may soon produce the 802.11ad standard that is expected to provide 1 Gbps+ data rates to extend the Wi-Fi speed limit. Maybe we don't generally need that speed for most operations but we are going to get it anyway. Isn't that just the way of electronics? **NV**

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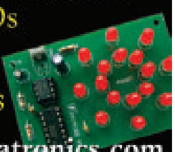

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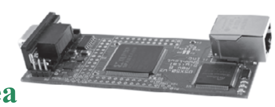

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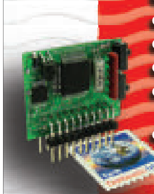

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- *home automation*

Ideal for college and hobby projects!

- tiny, light-weight module
- choice of 8K or 32K EEPROM
- SCI, SPI, pulse accumulator
- generate pulses, PWM, etc.
- measure time, frequency, etc.
- 14 digital I/O lines + interrupts
- use Assembler, BASIC, or C
- lots of code examples/tutorials
- easy Windows code-loading
- Starter Packages from $49

www.MicroStamp11.com

News Bits

On 25th Anniversary, TETRIS® More Popular Than Ever!

Video game industry legends Henk Rogers and Alexey Pajitnov announced the kickoff of the 25th anniversary celebration for TETRIS. TETRIS is one of the world's most popular casual computer games with over 125 million products sold on more than 30 platforms and available in more than 50 countries.

In June 1984, Pajitnov, a Russian-born mathematician wrote the program for TETRIS in his spare time. His love of puzzles inspired him to create a game where players arranged distinctive puzzle pieces in real time along the bottom of the rectangular playing field or "matrix" in order to clear lines. "For a short time, I was the best TETRIS player in the world," he said.

Rogers and Pajitnov said TETRIS is not resting on its laurels. "We have exciting plans for the future of TETRIS," said Pajitnov. "We want to make TETRIS more accessible to kids, boomers, and busy moms — everyone who enjoys a fun, stimulating and even meditative short escape from the daily grind."

Said Rogers, "The best is yet to come. We're working on versions of TETRIS that will make it possible to have 'international' games similar to the Olympics, or the World Cup. The next generation of TETRIS games will align themselves to the user — so they can always be exactly what best fits any specific individual — 'smart' TETRIS games that quickly 'learn their partner' and adjust to give maximum game play satisfaction."

TETRIS is also growing online. In March 2009, Rogers and Pajitnov teamed up with Minoru Arakawa to announce the launch of Tetris Friends Online Games (**www.tetris friends.com**), the first and only official Web-based TETRIS game destination in North America. Over one million TETRIS games are played per day on the website.

Freescale Achieves New ZigBee® RF4CE™ Certification

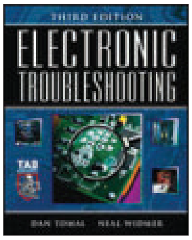
Freescale Semiconductor has received the new Golden Unit certification by the ZigBee Alliance for its successful implementation of the ZigBee RF4CE specification. Freescale is one of the first ZigBee Alliance members to achieve the Golden Unit status and has been an influential contributor in the development of the ZigBee RF4CE protocol.

Due to limitation of infrared remote controls with large screen, flat panel TVs, and the increased need for richer user interfaces and new services, RF-based remote controls are becoming pervasive in the home entertainment market, creating a greater need for standards. ZigBee RF4CE is expected to enable advanced control capabilities (i.e., two-way communication between entertainment devices) to continue to improve the overall usability of home entertainment products.

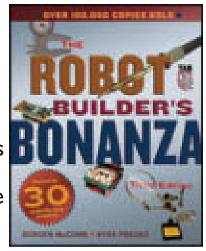
We have over 170 related titles in our webstore!!

The Nuts & Volts WEBSTORE

"EDITOR'S PICKS"



Electronic Troubleshooting
Developing electronic troubleshooting skills can take years — or a few months with the proper resources at your fingertips. *Electronic Troubleshooting* is one of those resources. Not only does it provide a modest degree of handholding for readers new to the myriad test equipment available today, but the authors offer heuristics developed from their years of practical experience in the art of troubleshooting. This is a good book for beginners.
$49.95*



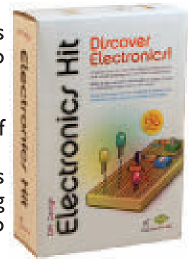
Robot Builder's Bonanza

Virtually all electronics projects involve both components and some sort of mechanical assembly. Often, it's too easy to focus on the electronics and forget about the mechanical systems. *Robot Builder's Bonanza*, while focused on robotics, provides a wealth of information for every hobbyist who wants to integrate hardware and software. If you work with motors, sensors, and hardware platforms, you owe it to yourself to add this reference source to your bookshelf.
$29.95

Editor Bryan Bergeron's recommended reads.
Find these and many more great titles in the *NUTS & VOLTS* Webstore!

ELECTRONIC NEWBIE

DIY Design Electronics Kit



This great kit contains everything you need to learn the basics of electronic circuit design. It contains all of the most common electronics components as well as a prototyping breadboard for you to get started right away.

The kit has over 130 parts!

No soldering is required and the included 32 page illustrated manual guides you through each of the projects. After you build all of the projects, you can use the parts for your own designs.

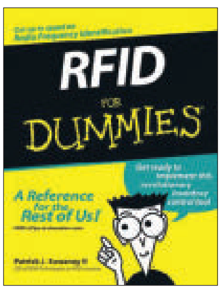
NEW!

For a complete product detail, please visit:
http://store.nutsvolts.com **$49.95***

ELECTRONICS

NEW!

RFID For Dummies
by Martin P. Bates

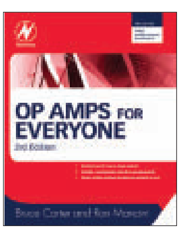


Discover how RFID can save your business money.

See what goes into an RFID set-up, choose your equipment, and test your system.

Is the rush to implement RFID causing you sleepless nights? Take heart! As more and more retailers require their suppliers to get on the RFID bandwagon, this book can save the day. Even if you're IT challenged and skipped physics class, you'll discover how RFID works and how to set up and deploy your network — just in time.
$24.95

Op Amps for Everyone, Third Edition
by Bruce Carter and Ron Mancini



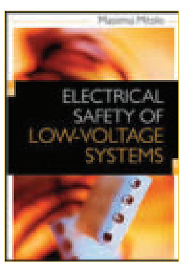
OP AMPS FOR EVERYONE provides the theoretical tools and practical know-how to get the most from these versatile devices - this new edition substantially updates coverage for low-speed and high-speed applications, and provides step by step walkthroughs for design and selection of op-amps and circuits.
$79.95*

Making PIC Microcontroller Instruments and Controllers
by Harprit Sandhu

Harness the power of the PIC microcontroller unit with practical, common-sense instruction from an engineering expert. Through eight real-world projects, clear illustrations, and detailed schematics, *Making PIC Microcontroller Instruments and Controllers* shows you step-by-step how to design and build versatile PIC-based devices. Configure all necessary hardware and software, read input voltages, work with control pulses, interface with peripherals, and debug your results.
$49.95*

Electrical Safety of Low-Voltage Systems
by Massimo Mitolo

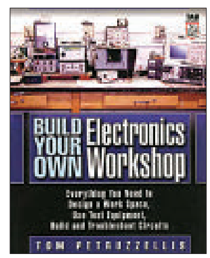
NEW!



Find all the information you need to minimize accident rates and ensure low-voltage system safety. *Electrical Safety of Low-Voltage Systems* offers you a comprehensive safety regimen, based on the fundamental characteristics of low-voltage electrical systems. Fully explains the grounding and bonding of low-voltage systems as they relate to article 250 of the National Electrical Code. **$89.95***

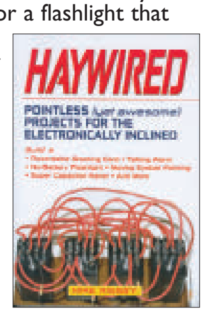
Build Your Own Electronics Workshop
by Thomas Petruzzellis

YOUR DREAM ELECTRONICS LAB IS WAITING INSIDE!



This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems — popular electronics author Tom Petruzzellis' *Build Your Own Electronics Workshop* has it all! And the best part is, this book will save you money, big time!
Reg **$29.95** **Sale Price $24.95**

Haywired
by Mike Rigsby



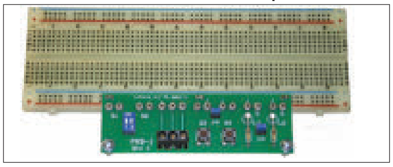
Construct a no-battery electric car toy that uses a super capacitor, or a flashlight that can be charged in minutes, then shines for 24 hours. Written for budding electronics hobbyists, author Mike Rigsby offers helpful hints on soldering, wire wrapping, and multimeter use. Each project is described in step-by-step detail with photographs and circuit diagrams. Includes websites listing, suppliers and part numbers.
$16.95

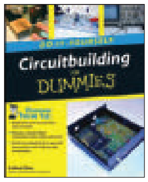
Order online @ www.nutsvolts.com
Or CALL 1-800-783-4624 today!

BOOK & KIT COMBOS

Proto Buddy Kit & Book Combo

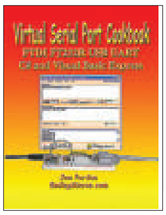
For those just getting started in electronics as a hobby, a solderless breadboard (SBB) is the perfect platform for building those first circuits. Attach a Proto Buddy to an SBB, include a battery or two, and you will have a combo that has a lot of the same functionalities as more expensive units.





Combo includes PCB & Components, 830 point SBB, and *Do-it-Yourself Circuitbuilding For Dummies*.

Combo Price $57.95 Plus S/H
Limited time offer.



Virtual Serial Port Cookbook

by Joe Pardue
As talked about in the *Nuts & Volts* June issue, "Long Live The Serial Port"

Book **$44.95**

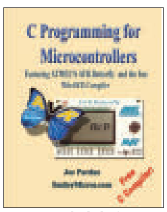
Kit **$69.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

The Virtual Serial Port Parts Kit and CD

(also *available, above right*)

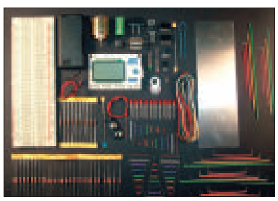
Reg. Price $ 114.90 **Subscriber Price $109.95 Plus S/H**



From the Smiley Workshop

C Programming for Microcontrollers

by Joe Pardue



Book **$44.95**

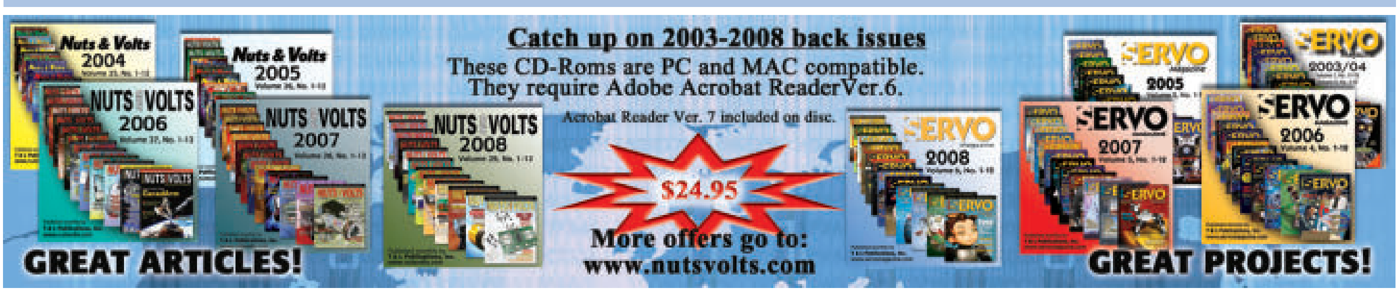
Kit **$66.95**

Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board and the FREE WinAVR C compiler to make a veryinexpensive system for using C to develop microcontroller projects.

Combo Price $99.95 Plus S/H

THE EVIL GENIUS SERIES

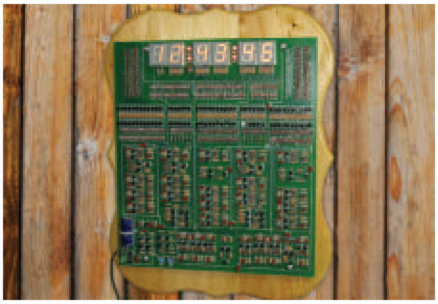
CD-ROMS



CALL 1-800-783-4624 today!
Or Order online @ www.nutsvolts.com

It's TIME to Build! PROJECTS

Transistor Clock Kit



If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components! For more info, see page 42, this issue.

Subscriber's Price **$214.95**
Non-Subscriber's Price **$225.95**
PCBs can be bought separately.

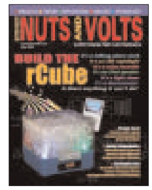
Arch-Ball Clock PCB & MCU

This unique clock allows the hobbyist to be involved with a little wood working, as well as the electronics side of the project. We just supply you with the custom shaped printed circuit board and the programmed MCU. You'll have to go digging in your workshop for the other components and wood.

Subscriber's Price **$25.75**
Non-Subscriber's Price **$28.25**
Arch templates can be downloaded from the *Nuts & Volts* website.

rCube Talking Alarm Clock KIt

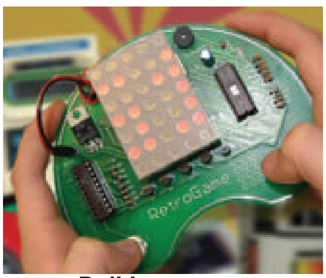
As seen on the May 2009 cover



Available in blue, black, red, and green. All components are pre-cut & pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

Subscriber's Price **$49.95**
Non-Subscriber's Price **$54.00**
PCBs can be bought separately.

Retro Game Kit



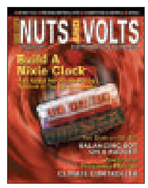
Build your own "BLAST from the Past!"

This is sure to be a hit for all ages! Easy to build in an evening and will give you many more fun filled evenings mastering the Retro Rover or Retris games. Games come preprogrammed on induvidual MCUs

Subscriber's Price **$39.95**
Non-Subscriber's Price **$44.95**

Nixie Tube Clock Kit

Cherry Wood Clock Case



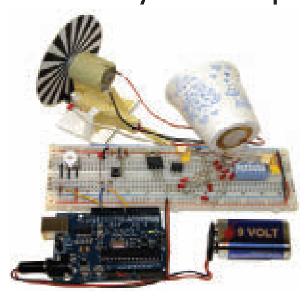
October 2006

Nixie tube clocks fuse the spirit, drama, and eerie beauty of cold war technology with modern inner works to create uncommon handcrafted timepieces.

Now with optional case choices! Get more info @ www.nutsvolts.com

Subscriber's Price **$146.95**
Non-Subscriber's Price **$159.95**
Kit includes article reprint, complete instructions and parts list.

Arduino Project Kit From the Smiley Workshop

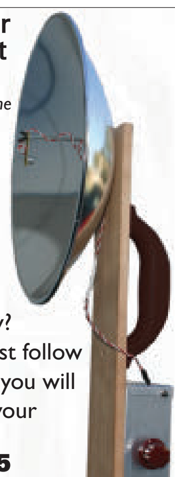


Blink LEDs (Cylon Eyes). Read a button and 8-bit switch. Sense Voltage, Light, and Temperature. Make music on a piezo element. Sense edges and gray levels. Optically isolate voltages. Fade LED with PWM. Control motor speed and more.

Price $79.95 Plus S/H

Big Ear Big Kit

As seen on the December 2009 cover

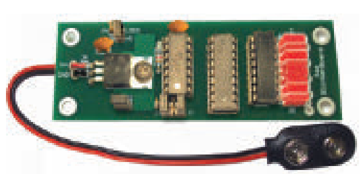


Ever wish you could build an "audio telescope" that would let you hear things that were faint or far away? Then this kit is for you! Just follow along with the article and you will see how to put together your own "BIG EAR!"

Subscriber's Price **$98.95**
Non-Subscriber's Price **$111.95**
Kit Includes an article reprint.

Das Blinkenboard Kit

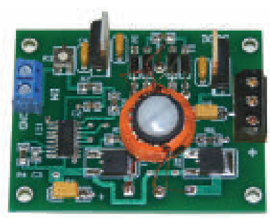
This kit includes a preprogrammed ATtiny84 microcontroller that sports eight software PWM channels to control motor speed and light brightness. Jumper selectable patterns can be used to operate motors, solenoid valves, relays. Expand your board with GNU/GPL software updates to be featured in upcoming *NV* articles.



Subscriber's Price **$32.45**
Non-Subscriber's Price **$35.95**
PCBs can be bought separately.

DC-to-DC Converter Kit

As seen on the March 2009 cover



"Roll Your Own" Transformer that is!

With this project, you design and wind a transformer and use it to get +12V and -12V from a 9V battery from the DC-to-DC converter.

Subscriber's Price **$37.49**
Non-Subscriber's Price **$39.95**
Cores, and Bifilar can be bought separately.

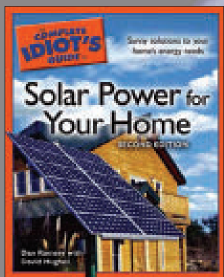
WE ACCEPT VISA, MC, AMEX, and DISCOVER. Prices do not include shipping and may be subject to change.

Attention **Subscribers ask about your discount on prices marked with an ***

The Nuts & Volts **WEBSTORE**

ALTERNATIVE ENERGY SECTION

The Complete Idiot's Guide to Solar Power for Your Home
by Dan Ramsey / David Hughes



The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems. **$19.95**

Do you know how many watts (YOUR MONEY) are going down the drain from "THE PHANTOM DRAW?"

If you are interested in your own power usage we at *Nuts & Volts Magazine* believe that this is the best way to help you determine your electrical energy use in ON and OFF home appliances.

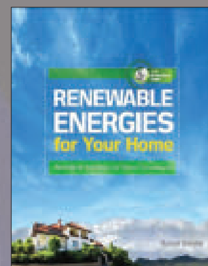
To order call 1 800 783-4624 or online www.nutsvolts.com

$29.95 plus S&H

Renewable Energies for Your Home
NEW!

by Russel Gehrke

Simple and Inexpensive Renewable Energy Solutions for Your Home.

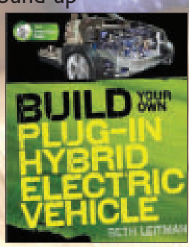


It's not always easy being green, and sometimes it costs more than you'd expect to get an eco-friendly home improvement project up and running. *Renewable Energies for Your Home* gives you sustainable home energy solutions that won't drain your wallet or the power grid. Filled with step-by-step instructions and helpful photos and illustrations. **$24.95**

Build Your Own Plug-In Hybrid Electric Vehicle
NEW!

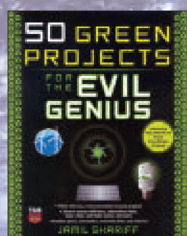
by Seth Leitman

A Step-by-Step Guide to Building a Plug-In Hybrid Electric Vehicle from the ground up



Build Your Own Plug-In Hybrid Electric Vehicle puts you in the driver's seat when it comes to hitting the road in a reliable, economical, and environmentally friendly ride. Inside, you'll find complete details on the hybrid powertrain and all the required components, including the motor, battery, and chassis. **$24.95**

50 Green Projects for the Evil Genius
by Jamil Shariff

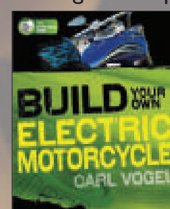


Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life! **$24.95**

Build Your Own Electric Motorcycle
NEW!

by Carl Vogel

A practical guide for building an electric motorcycle from the ground up.

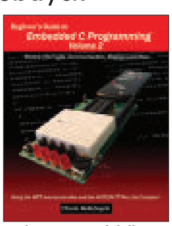


Complete with hundreds of step-by-step pictures, charts, and graphs for the latest and most efficient technologies, this new TAB Green Guru Guide shows you how to build an electric motorcycle from scratch. Written by an electric vehicle expert, *Build Your Own Electric Motorcycle* provides current data on all required materials, components, and specifications. **$24.95**

SPECIAL OFFER

Beginners Guide to Embedded C Programming. Volume 2
NEW!

by Chuck Hellebuyck



In this "Volume 2", Chuck takes the reader to the next level by introducing how to drive displays, how to use interrupts, how to use serial communication, and how to use the internal hardware peripherals of the PIC16F690 microcontroller such as SPI, PWM, and timers. When you have finished reading this book and completed the projects, you'll be well beyond the title of Beginner!

Reg $39.95

Limited Time Offer $35.95

TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

QUESTIONS

To be considered, all questions should relate to one or more of the following:

1. Circuit Design
2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.
- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions are subject to editing.

ANSWERS

- Include in the subject line of your email, the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.
- Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Lead Connections Of 280 Amps MOSFET

The MOSFET leads in a TO-220 package to carry about 280 amps look small — about 1 sq mm cross section — though short length.

What is the best way to connect the drain and source terminals/leads and what size heatsink is required to 250 watts for a 2,500 watt inverter?

#8091 Mohammed Ahmad
Mississauga, Ontario, Canada

SMPS Ripple Scrubber

What remedies might there be to further scrub the ripple from an otherwise very competent SMPS? As I am learning, they are smart little buggers, and simply throwing a farad or two worth of mondo blue caps between it and my headphone amplifier is not a remedy. I would like to stay outside of the unit itself. Any suggestions or references would be appreciated.

#8092 Bruce Seidner
Knoxville, TN

Battery Powered Hand/Foot Warmer

I help coach a high school ski racing team. As a consequence, I spend a lot of time standing in the snow and my hands or feet sometimes get cold. I would like to have a circuit to build a battery powered hand/foot warmer. Ideally, the circuit would regulate the power output of the resistor to maintain a preset temperature measured with a thermistor. The preset temperature point should be variable and able to be adjusted at any time. I plan to use four AA NiMH batteries in series.

Energy = 2600 mAh x 4 x (4 x1.5V) = 15.6W-hr

If I want it to last eight hours at 100% duty cycle:

Average Power = 15.6W-hr / 8 hr = 2W

Average current = 2W/6V = 333 mA

Resistor = 6V/333 mA = 18 ohms

It would also be nice to have an ON LED, and an LED that indicates when current is flowing to the resistor would help in adjusting the temperature set point.

#8093 Mark Smith
Corvallis, OR

HVAC Controls On A Computer

What do they have that will tie HVAC controls on a computer for home and commercial applications?

#8094 Paul Finnigan
Arlington, VA

Heart Rate Monitor

I need to build a heart rate monitor to see when my wife's heart rate gets too high. I have the standard finger model, but I would like something that uses chest probes and I could record the actual signal.

What is a circuit that I can front-end a PIC with to record and save data?

What is a circuit that will receive just the pulse data from a sports heart monitor's chest strap I can use to interface a PIC with?

#8095 **Steve**
via email

RFID

I have a small project I'd like to build, but it involves using an RFID transmitter chip and receiver, and I'm having trouble finding a source for small quantities of parts. For testing purposes, I only need one or two transmitters and one receiver. I'd like a reception range of about 2-3 feet. Application notes would also be helpful.

#8096 **Ed Frisa**
Cincinnati, OH

Need LCD Datasheets

I am looking for datasheets or advice on how to use an LCD unit salvaged from a mid 1980's medical device. The PCB is labeled "PWB641C-CEM, OPTREX." There are 19 pins, two of which are "A" and "K" which I believe to be power for the backlight. The chips are "HD44105H" and two "HD44102CH."

#8097 **Alan Rutner**
Cromwell, CT

>>> ANSWERS

[#3096 - March 2009]
Digital Multimeter Input Impedance

I have purchased an inexpensive DMM which appears to work satisfactorily. Is there a method to measure the input impedance of the meter?

The easiest way to measure the input impedance is to use a battery and resistor. Take a fresh AA battery and measure the voltage using the meter you want to test. Set the meter on the appropriate range (2V) and measure the battery voltage and record your reading as Vb. It should be around 1.5V to 1.6V. You can use any value resistor that is relatively close to the impedance you want to check. The closer it is, the more accurate your measurement will be. A factor of 10 is close enough. Since most DMMs are 10 to 100 Mohms, a 10M resistor is a good choice.

Anything between one and 100 megs should work unless you need precise numbers. Place the resistor in line with the battery and measure the voltage and record it as Vm. Rs is the value of the resistor you used and Rm will be the calculated impedance of the meter.

*Rm = (Vm * Rs) / (Vb - Vm)*

For example, I grabbed a used AAA battery, my meter off my bench, and a 1 Mohm resistor (Rs). I measured the battery alone (Vb) at 1.486V and with the resistor in series at 1.362V (Vm). I calculated this:

*Rm = (1.362 * 1,000,000) / (1.486 - 1.362) = 10,983,871 ohms or 10.98 Mohms.*

Will Cooke
Clarksville, TN

[#4091 - April 2009]
Stereo TV Volume Regulator

On several cable channels, commercials are much louder than normal programming, or the volume level changes annoyingly during a program. Does anyone have a circuit that can be built into a stereo TV to provide an "AGC" function?

#1 Volume regulation is a fairly complex matter to solve; it has to be fast in response and at the same time offer very little distortion.

TERK Corp. markets their VR-1, which hooks up to the external audio jacks of a device (i.e., VCR) to feed the TV. It uses Digital Signal Processing (DSP) and has a very fast attack time — .002 seconds. Marketed by several distributors, one is MCM Electronics.

We all need to petition the broadcasters to "ride" their audio better. I have a real problem with cable providers not having consistant levels. Problem is, they don't know how.

Rod Hogg
REVCOM Electronics
Scott City, KS

#2 George Nutzul's problem regarding a volume limiter would be easily solved by using a compressor /limiter supported by a NTE1634 dual preamp w/ALC integrated circuit. I have used this device with great success in several applications involving audio limiting and compression. It is available from many sources for about \$3-\$4. To get the circuit design, search the Internet for a Samsung KA2224 IC. Their datasheet gives a nice sample circuit for a tape recording preamp with automatic volume control. I used only the record functions — eliminating the playback components — as they do not have the ALC functions. I powered the unit from 8-12 volts with no problems. I also eliminated the diode with the anode connected to ground for a very wide dynamic range. For the germanium diodes, I used an old germanium trasistor emitter/base junction with the collector not connected. There are many NTE small signal germanium transistors available if you don't have any leftovers. An NTE 102 would work fine. Adjustment of input and output levels will require potentiometers to get the levels compatible with your particular installation, and be sure to use coupling capacitors of about 4.7 µF on inputs and outputs, as the Samsung circuit doesn't show them.

Robert Soltysik
McKinney, TX

[#4092 - April 2009]
DC To AC Inverter For The Grid

Does anyone have a solution with a schematic on how to sync a modern inverter like those from Harbor freight — say their 700 watt model — to the grid? (Very important for anyone working with solar and the green problem!)

An inexpensive inverter cannot and should not be used to feed or sell power back to the grid. Here's the "cannot" part. **Figure 1** shows a 60 cycle per second (60 Hertz) sine wave that represents the waveform of a 120 volt AC grid power. The voltage varies as a sine wave with a peak at 170 volts every half cycle. The integral of this waveform — also known as the RMS (root-mean-square) value — is 120 volts. The second waveform in the figure shows the signal that the

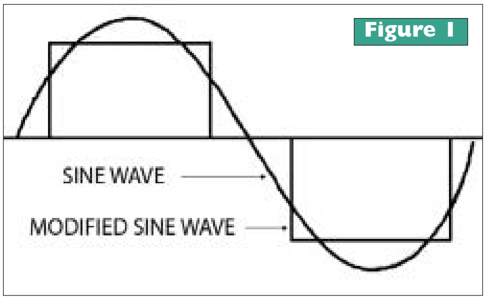


Figure 1

Inverter and UPS industry calls a "modified sine wave." As you can see, it is not a sine wave at all. It is a square pulse that goes from 0V to 140V and back to 0V during the center of each half cycle. This is really a modified square wave, but "modified sine wave" is much easier to sell! Manufacturers use this because it works for many devices — a notable exception is induction motors in fans and large appliances — and it is cheap to produce.

Inverters that produce sine waveforms are always advertised as "true sine wave" inverters. They cost a lot more and are usually only available in larger capacities of 1,000 watts or more. The incompatible waveforms are one reason you cannot use a modified sine wave inverter to feed power back to the grid. Another technical hurdle is that small inverters are 120V single phase, while the power coming from the grid to most homes and small businesses is a 240 volt split phase, and large buildings use three phase. You cannot drive only one 120 volt phase without damaging the power company's transformer.

Here is the "should not" part — there are many legal and safety issues to consider. For instance, a cheap inverter is not smart enough to turn itself off in a grid blackout. This runs the risk of causing injury — or worse — to a power company lineman who thinks his line is cold but thanks to your inverter it is hot. There are also electrical and fire safety issues regarding power factor, over and under voltage, over current, ground fault, etc. For all of these reasons, it is big time illegal to connect anything to the electrical grid unless it is specifically approved for that use and your local electrical inspector approves the installation.

If you want to sell power back to the grid, you need what is known as a "grid-tie inverter." These are specialized devices designed to convert your alternative power source to grid-compatible power, and to transfer that power safely and efficiently to the grid. Some allow you to connect batteries for off-line backup use, while some just connect the alternative power source directly to the AC grid. They are readily available on the Internet in capacities from 1.5 KW to 5 KW, and cost around $2,000 at the 3 KW level.

Mark Lewus
Denville, NJ

[#4093 - April 2009]
Linear Generator

I need an efficient linear power generator. Any ideas how to make one? Perhaps using a voice coil style or moving magnet in a coil/tube setup. It must be as efficient as possible and able to handle direction and voltage polarity change so that electrical output is maintained at 12 VDC or as close as possible. It needs to work with a push rod with a throw of 3-6 inches.

#1 Your range of throw distance is about 10 times the range for low cost linear motors/generators, by my experience. Consider the use of a rotary generator. These are more magnetically efficient because of being able to hold smaller magnetic air gaps via low cost bearings. Yes, a bridge rectifier will be needed because of polarity change with reversal of motion. To convert alternating, linear strokes to oscillating, rotary motions consider the use of a rack and pinion gearing or a "negator" spring. The "dime store" solution would resemble a miniature archer's bow with the string wound once around the shaft of a slot car motor/generator. This would resemble the Boy Scout's method of starting a fire without a match. Since a rectifier is already needed, search for a low cost, surplus, brushless motor/generator with a PM rotor. Its lower rotor inertia (sans commutator) would be easier to reverse at the ends of strokes and its inherent AC output would utilize the already present rectifier. Schottky diodes — with their lower forward voltage drop — could be used. Also, use as high a generator voltage as you can find to achieve the 12 volt output. Most low cost motor/generators are in the range of 3-6 volts at thousands of rpm.

William A. Hanger
Churchville, VA

#2 ProCooling has a drawing of a linear motor as part of a sterling cycle refrigeration compressor (see Reference 1). This linear motor will serve equally well as a generator. I have drawn just the linear motor part in **Figure 2** to show what a high efficiency linear machine looks like. If there is a secret to the efficiency of this design, it is what appears to be iron cladding around the coil. This provides a low reluctance path for the magnetic flux lines to complete a path around the outside of the coil to the ends of the magnet. Air gaps in the magnetic flux path need to be minimized. Note that the coil windings surround the moving magnet. I suppose the moving magnet flux cuts the split windings more efficiently.

The only problem I see with the ProCooling design is the short stroke compared to the long three to six inch stroke you want. If you opt for a long slender bar magnet moving in an equally long solenoid instead of the split winding, place the solenoid in a steel pipe to lower the reluctance of the magnetic path. That should improve the efficiency. Steel washers at the ends of the pipe should help, too.

[1] **www.procooling.com/index.php?func=articles&disp=47&pg=1**

Dennis Crunkilton
Abilene, TX

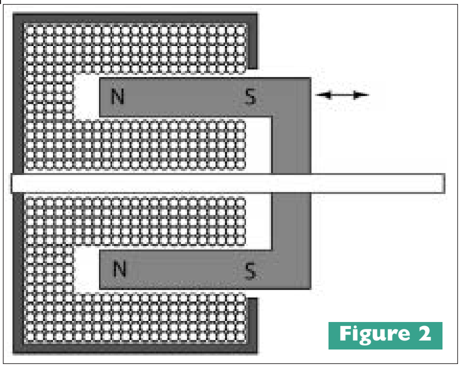


Figure 2

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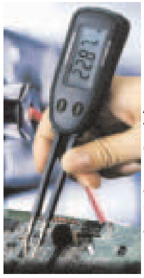

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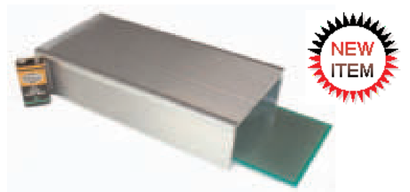

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PCB Size 50 x 20 x 152 mm 1.95 x 0.78 x 5.98 in	PCB Size 60 x 25 x 179 mm 2.36 x 0.98 x 7.04in	PCB Size 80 x 35 x 203 mm 3.14 x 1.37 x 3.98 in
Perfboard Specifications 20 x 57 plated thru holes on 0.1in centers on double-sided FR-4 board	Perfboard Specifications 24 x 67 plated thru holes on 0.1in centers on double-sided FR-4 board	Perfboard Specifications 32 x 77 plated thru holes on 0.1in centers on double-sided FR-4 board
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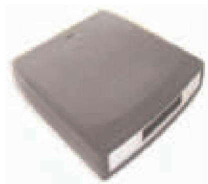

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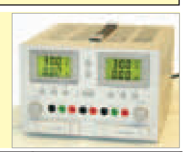

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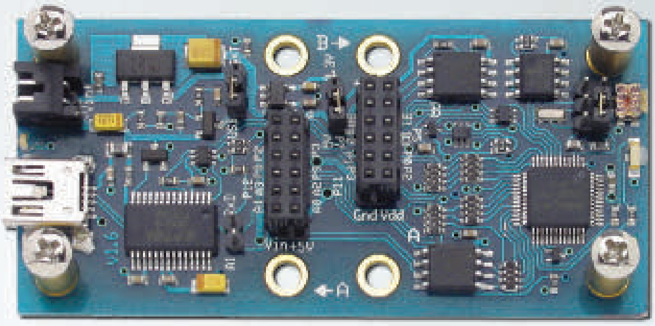
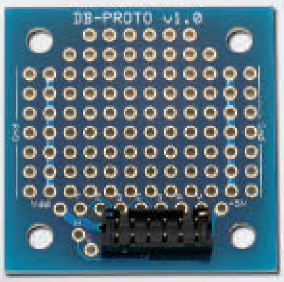
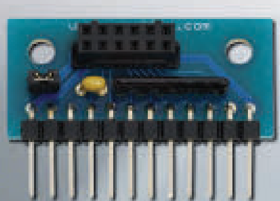


BASIC Stamp 2pe Motherboard *(#28300; $69.99)*



BS2pe Prototyping Daughterboard (#28310; $1.99) is a convenient through-hole board that allows you to build your own circuits with the MoBoStamp-pe.



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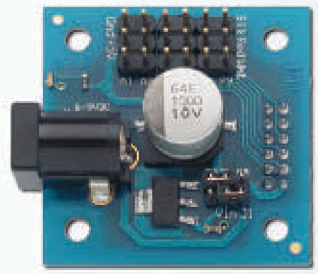

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